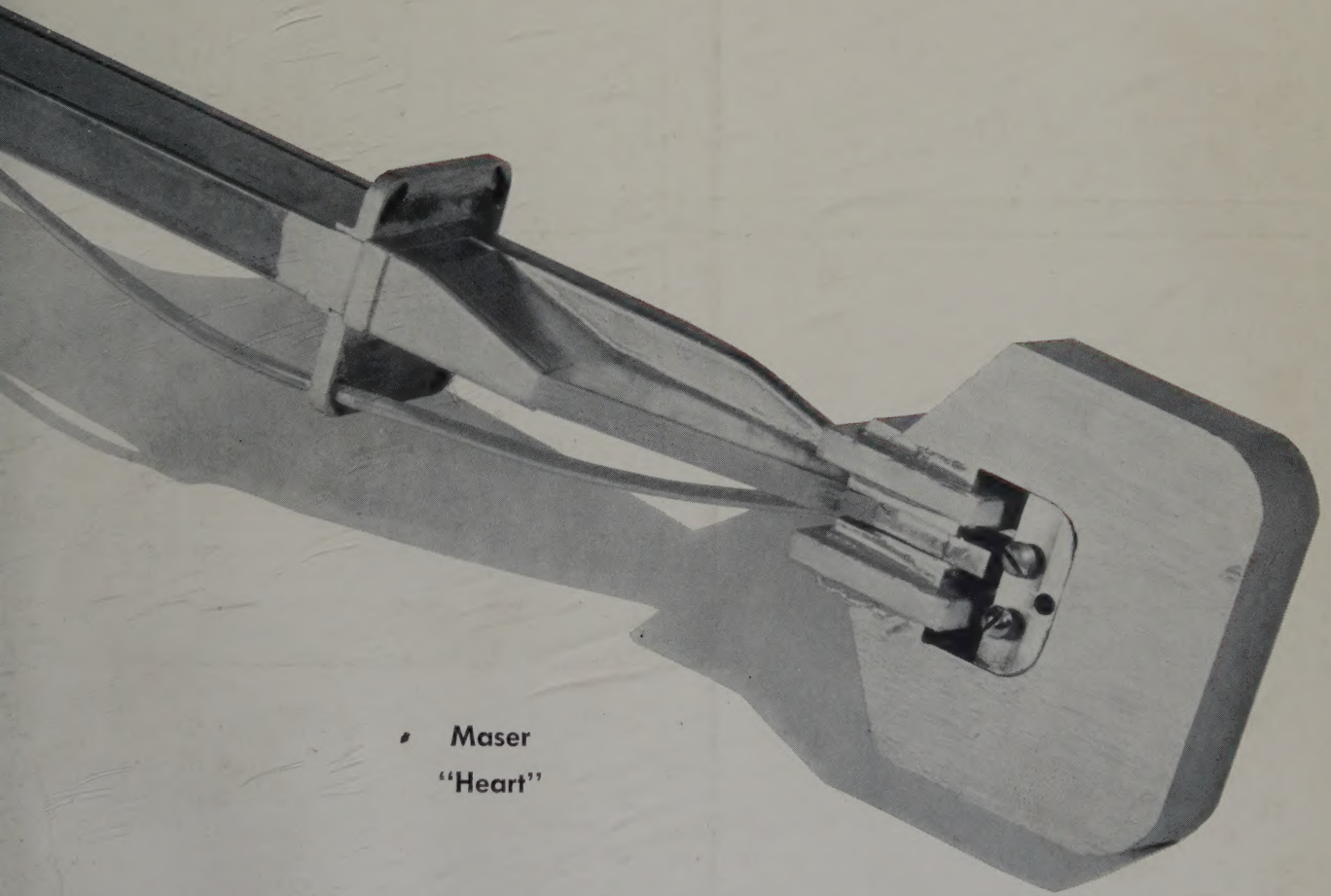


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• Maser  
"Heart"

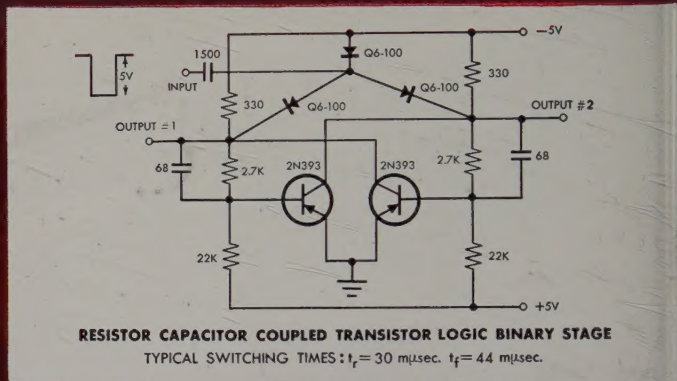
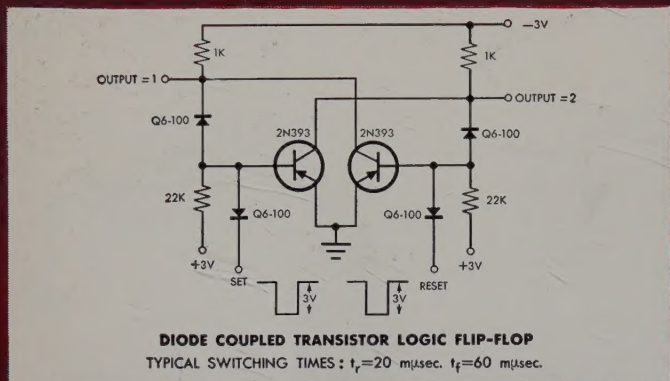
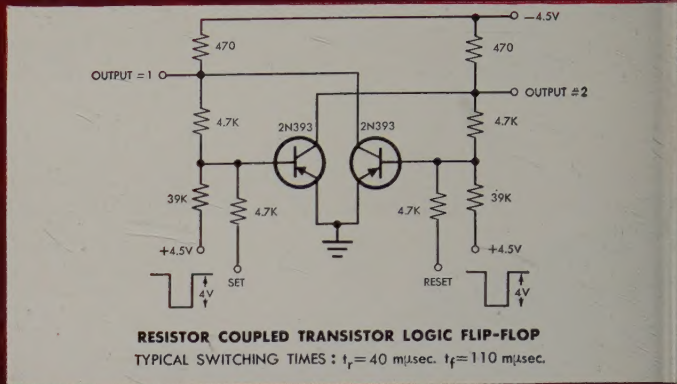
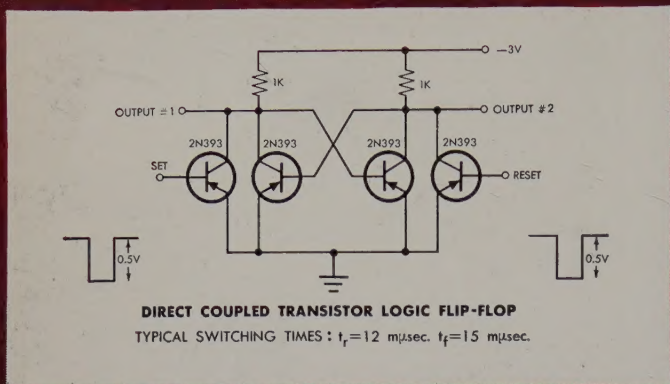
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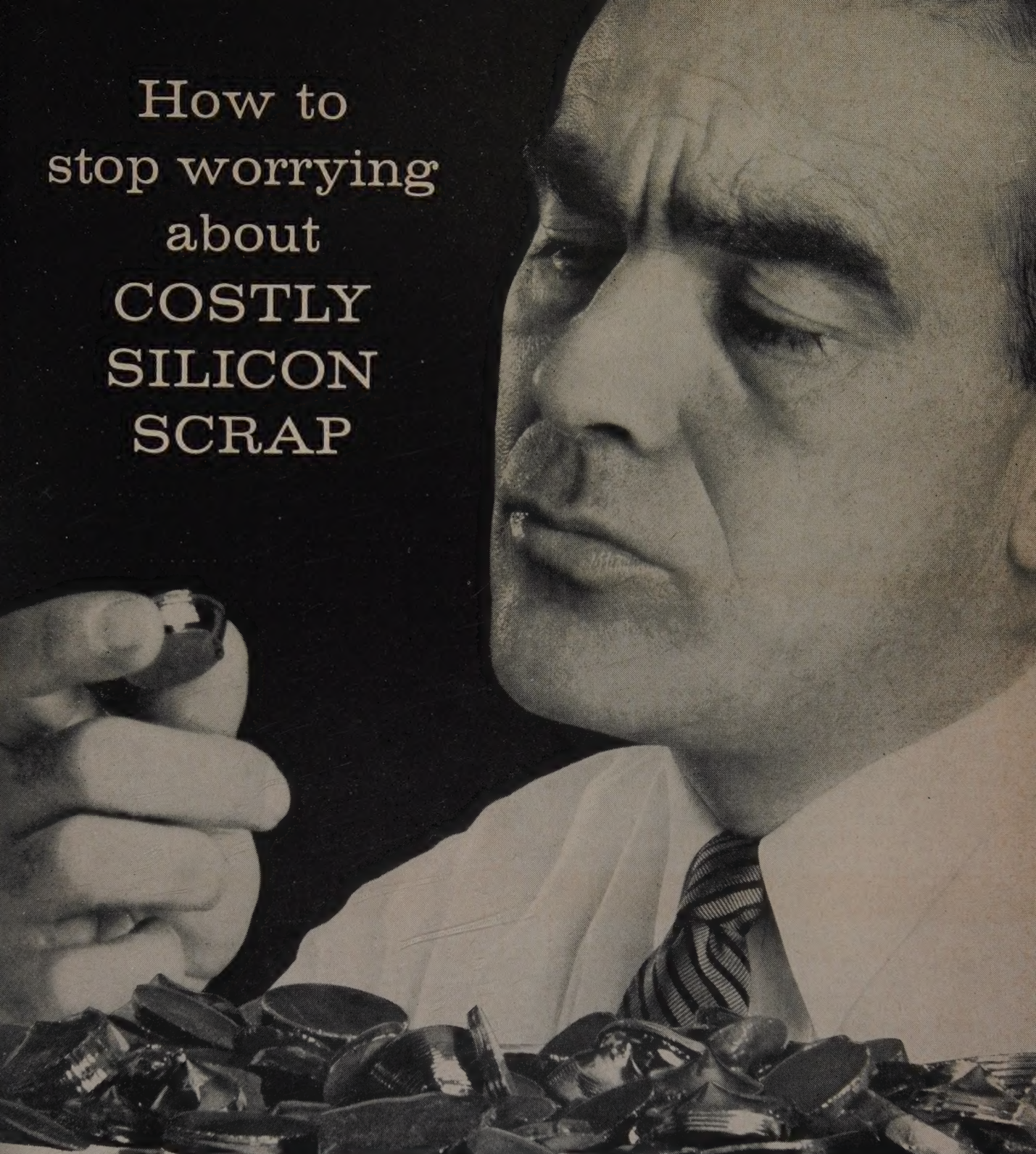
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# SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

May 1960 Vol. 3 No. 5

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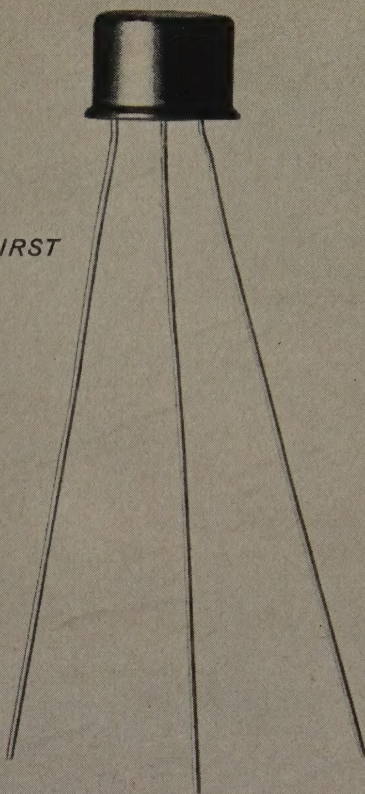
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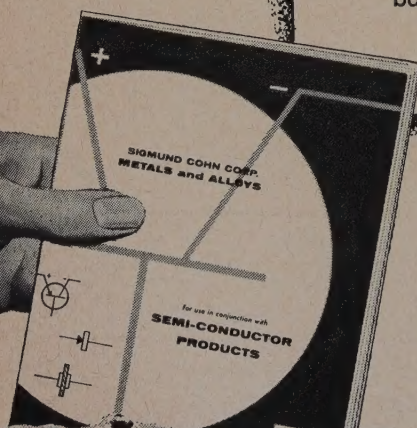
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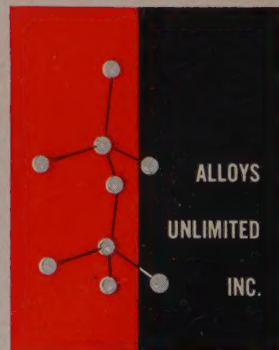
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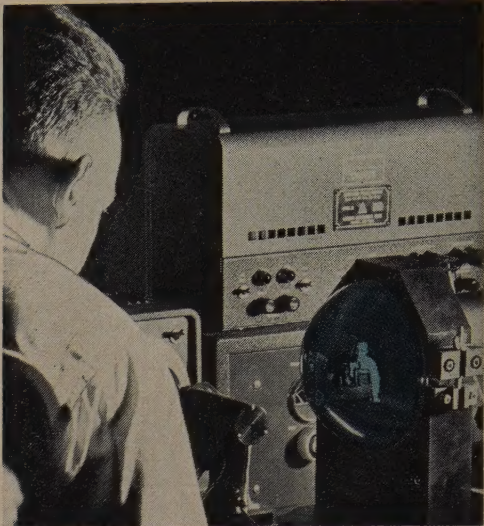
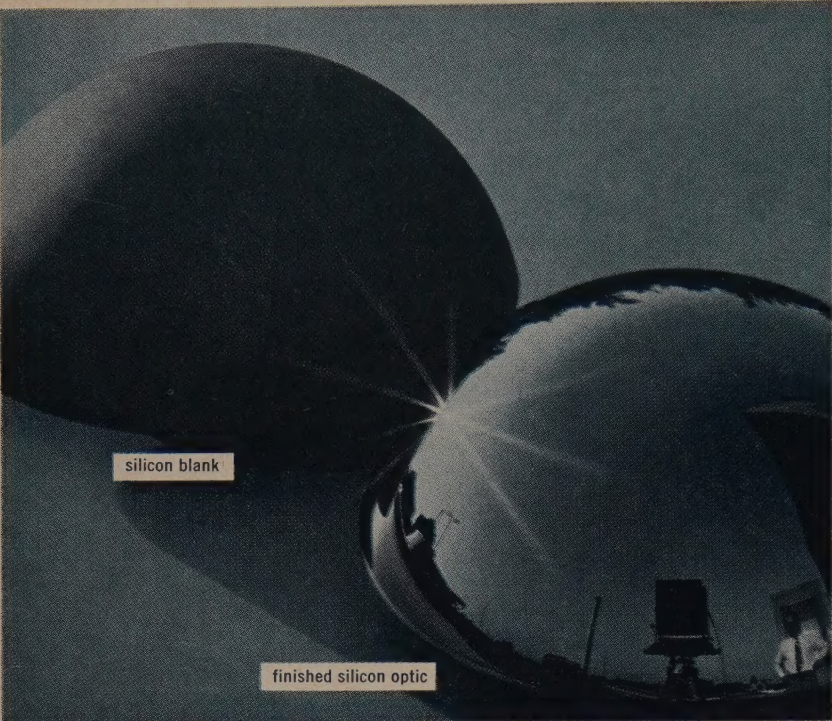


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Avion engineer “reflects” on Dow Corning silicon dome during test of infrared transmission characteristics. Avion’s capability in infrared technology dates back to early research and development on the famous “Sidewinder” missile. Present interests and projects include airborne detection and tracking devices.

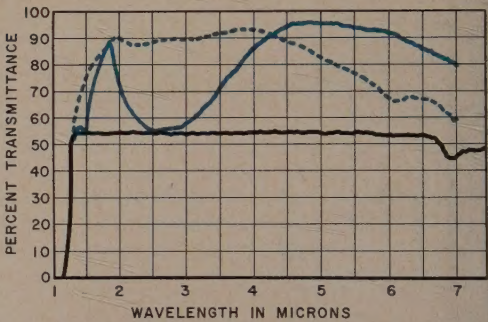
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	1150	Knoop
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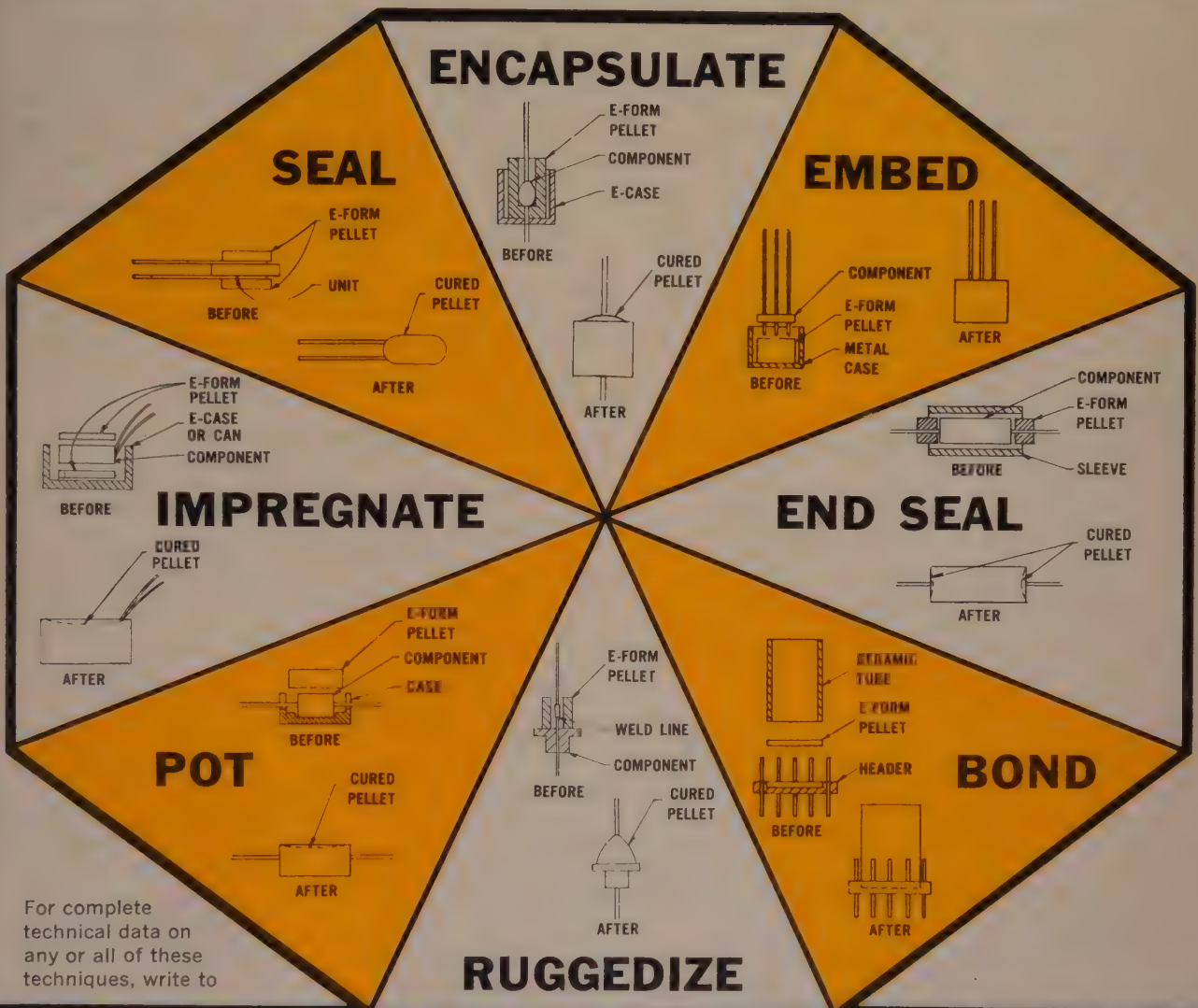


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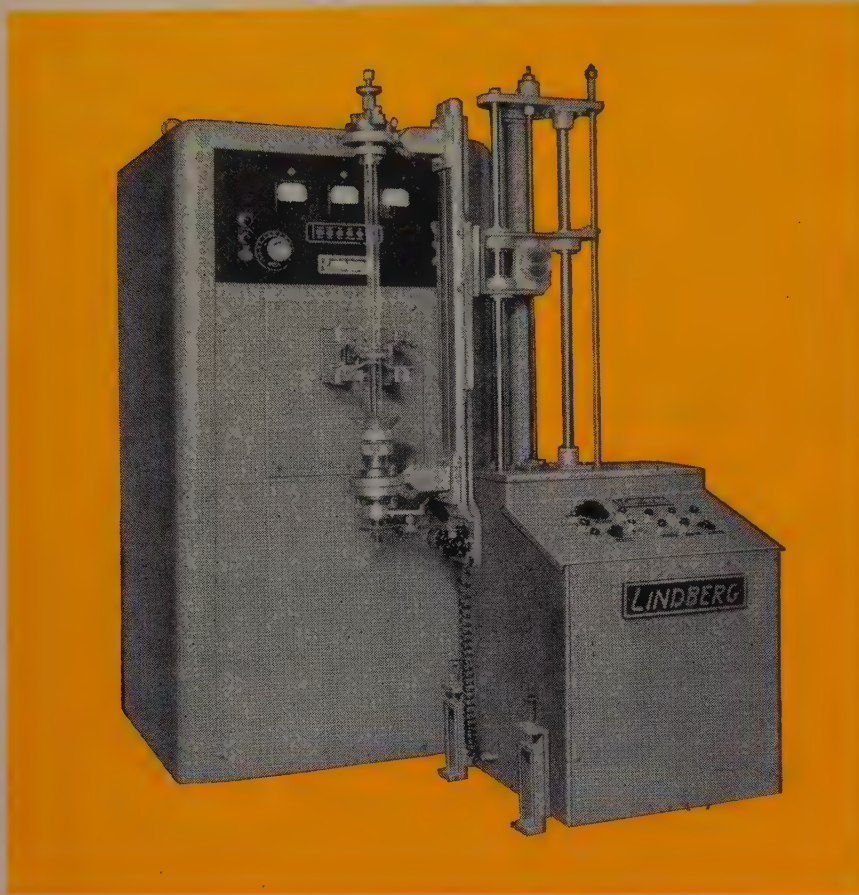
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## Book

**TITLE:** Masers

**AUTHOR:** J. R. Singer

**PUBLISHER:** John Wiley and Sons 1959

*Masers* is one of the first, if not the first, book describing the recently developed field of quantum amplifiers. The book comprises a unified approach to the topic not readily obtained from the many varied papers and published articles.

Chapters I and II comprise a simple understandable approach to the rather complex topic of quantum mechanics. The first chapter is a simplified description of the physical operation of the Maser and a historical review of developments. A complete bibliography at the end of the chapter refers the reader to the basic papers of the research workers. Chapter II is a mathematical treatment of the mechanics of the Maser; induced emission and absorption. The presentation starts with a discussion of a classical harmonic oscillator leading to considerations of energy interchange and finally absorption or induced emission as an outgrowth of the energy exchange polarity. The Einstein relationships and a discussion of amplification complete the chapters.

The third chapter deals with Gas Maser devices. The first quantum mechanical microwave oscillator, or ammonia "clock," is completely described here together with equations and relationships for power output, cavity design and random noise.

Chapter IV is a complete discussion of the phenomenon of electric paramagnetic resonance (EPR) of which the solid state maser is a special case. The classical description utilizing a rotating coordinate system may be found in section 4-3. The material presented considers the relaxation time, line breadth or band-width and overall quantum descriptions of the maser.

The balance of the book is devoted chiefly to a description of the two-level and three level amplifiers. The levels refer to the energy states that are useful in terms of the availability of "almost free" electrons. The processes of oscillation and amplification are treated and circuit diagram and typical equipment are discussed. The book closes with discussion of traveling wave masers. An excellent appendix derives various equations and compares masers and parametric amplifiers.

*Masers* is an excellent textbook for the serious microwave specialist. The material presented is well unified and clearly developed although a firm background in mathematics and physics, especially field theory is required for a thorough understanding. The early chapters however, give a good introduction to the Maser and should together with the rather complete bibliography aid in grasping the concepts.



# Reviews

**TITLE:** Electronic Designers' Handbook

**AUTHOR:** Robert W. Landee  
Donovan C. Davis  
Albert P. Albrecht

**PUBLISHER:** McGraw-Hill

*Electronic Designers' Handbook* is an up-to-date collection of design data, equations, circuits and information to aid the circuit development engineer. The value of any book of this type lies in the presentation and accessibility of data. In this regard the handbook is excellent.

The material is presented in twenty three sections. The first section groupings (from Sections 1 to 7) cover a general range of basic topics such as tube amplifiers, oscillators, modulation and transistors. The seventh section is valuable for its system and noise concepts in receivers. The material is presented in a threefold manner: a technical discussion, circuit and parameter evaluation and an illustrative example. The practical examples worked out for the transistor circuits are particularly valuable in the understanding of temperature stabilization and over-all gain.

A substantial portion of the book is devoted to pulse and pulse handling circuits. There are sections on multivibrators, sawtooth generators, trigger circuits, clippers, limiters and clamps. A limitation here is the lack of presentation of transistor circuitry for pulse work, however the vacuum tube considerations are excellent.

The balance of the handbook deals with electronic topics. The design of power supplies and iron core components are covered in Sections 14 and 15. Attenuators, equalizers and filters are discussed in the following two sections. An excellent treatent of principles of analogue computers and servomechanisms may be found in Section 19. The concluding chapters cover networks wave-form analysis, and antennas.

The *Electronic Designers Handbook* is concise, accurate and well written. The clarity of description and the numerous illustrative examples serve to enhance the work and increase the usefulness of this book.

By Stephen E. Lipsky

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One example: the development of a special borate coating for diode Dumet wire to provide anti-leeching characteristics. Another: Sylvania altered the alloy of the core rod in a special Dumet wire to assure the proper coefficient of expansion. For all wires, Sylvania maintains precise quality control throughout the manufacturing process.

Result—a consistently high quality product—and at low cost.

Whatever the metal—platinum, tungsten, molybdenum, copper, an alloy or composite wires such as Dumet—Sylvania technical skills add up to quality glass sealing wires. And in welded assemblies, cans, headers, connectors and alloy cuts and leads, you'll find you can brighten *your* quality—and profit—picture with Sylvania. Parts Division, Sylvania Electric Products Inc., Warren, Pennsylvania.

# SYLVANIA

*Subsidiary of* **GENERAL TELEPHONE & ELECTRONICS**



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SEMICONDUCTOR PRODUCTS • MAY 1960



# NOW AVAILABLE

FROM THE PIONEERS OF THE INDUSTRY

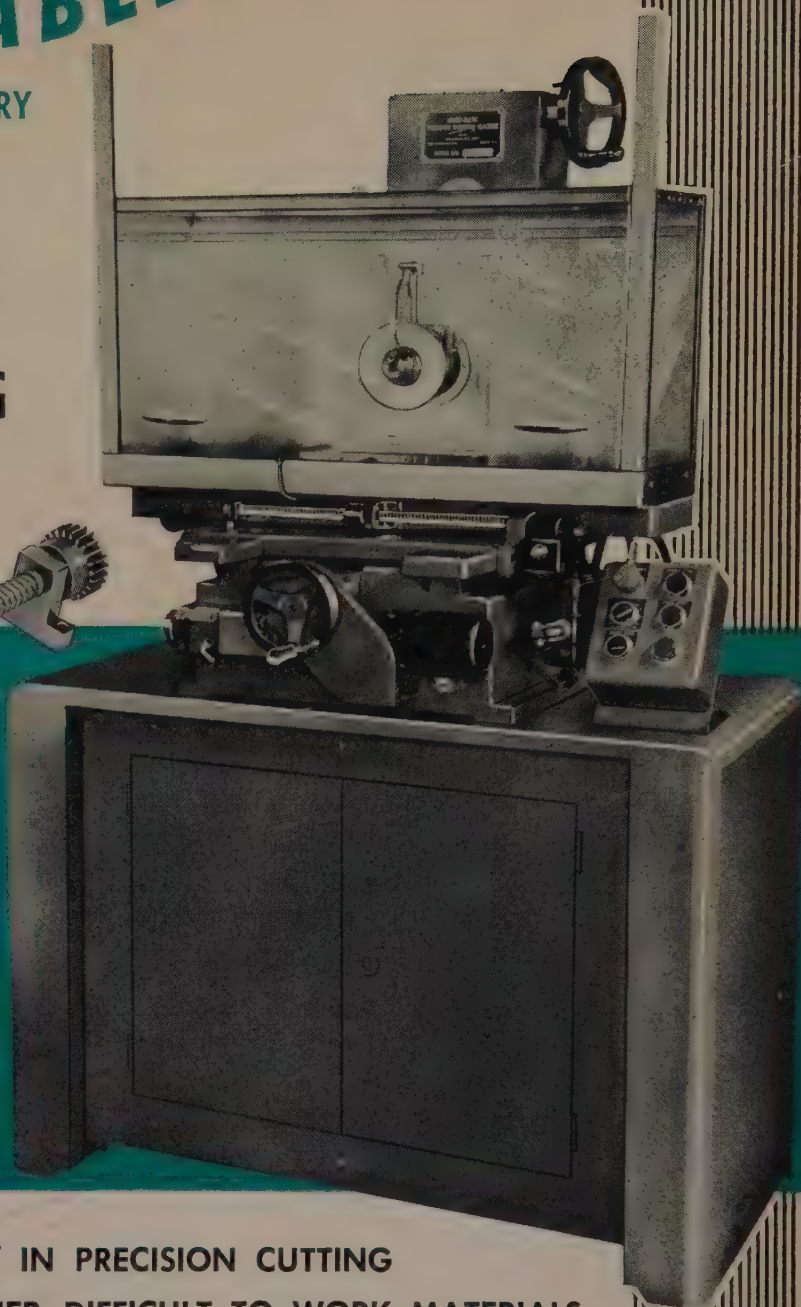
ADVANCED DESIGN

## *Micro-Matic* PRECISION WAFERING MACHINE

WITH THE

# NEW

# ROTON® TABLE DRIVE



INCREASES PRODUCTION EFFICIENCY IN PRECISION CUTTING  
OF GERMANIUM, SILICON AND OTHER DIFFICULT TO WORK MATERIALS

- Provides smooth, continuous and positive longitudinal table feed
- Gives faster return speed
- Eliminates motor burnout
- Insures better control over low speeds
- Virtually frictionless

*Also available for installation on your present equipment.*

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extremely pure, 'Baker Analyzed' *REAGENT*

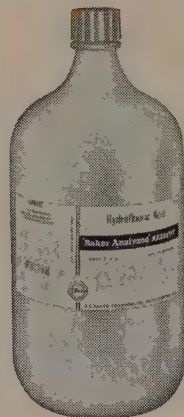
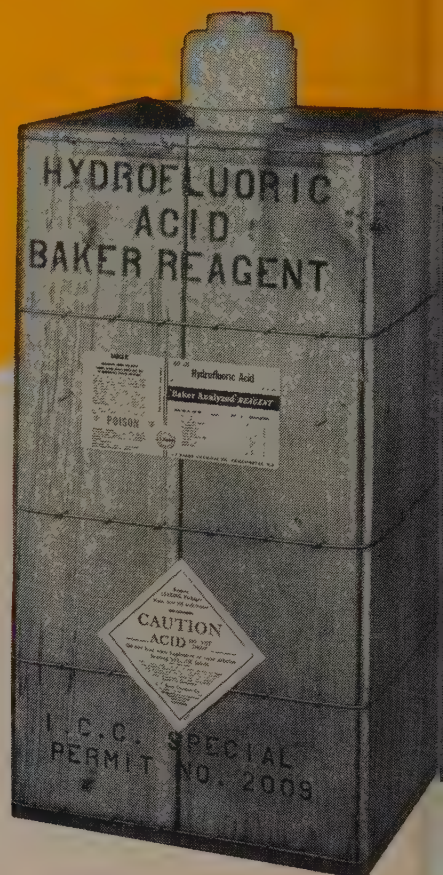
# HYDROFLUORIC ACID

in your choice of

## 3 CONTAINER SIZES

6½ GALLON POLYETHYLENE CARBOYS

10-LB. and 1-LB. NONRETURNABLE  
POLYETHYLENE BOTTLES



...functional,  
labor-saving packaging  
for your

## SAFETY • CONVENIENCE • ECONOMY

**HYDROFLUORIC ACID** is a key processing chemical.

To meet the sharply rising demand for Hydrofluoric Acid manufactured to J. T. Baker's exceptional standards of quality, Baker has once more expanded production facilities. In addition to dependable, on-time deliveries, Baker offers you:

**YOUR CHOICE OF CONTAINER SIZES:** 6½ gallon polyethylene carboys, 10-lb. and 1-lb. polyethylene bottles.

**SAFE, CONVENIENT, LABOR-SAVING PACKAGING:** Carboys and 10-lb. bottles expedite convenient handling of large quantities of acid. The Baker 1-lb. bottle makes possible more rapid pouring

than competitive 1-lb. containers and with an added safety factor: There's no diaphragm to puncture—no danger of "acid-spurt."

**PURITY:** Baker manufactures in conformance with extremely high standards of purity. Specifications assure that copper and nickel each will not exceed ½ part per million.

**ACTUAL LOT ANALYSIS:** Each container is labeled with the actual lot analysis defining copper, nickel and eight other significant impurities.

**ACTUAL LOT ASSAY:** You'll appreciate this "J. T. Baker extra" especially important for your use.

**FULL AVAILABILITY AND FAST SERVICE**—from expanded production facilities.



FOR PRICES AND ADDITIONAL INFORMATION, WRITE OR PHONE

**J. T. Baker Chemical Co.**

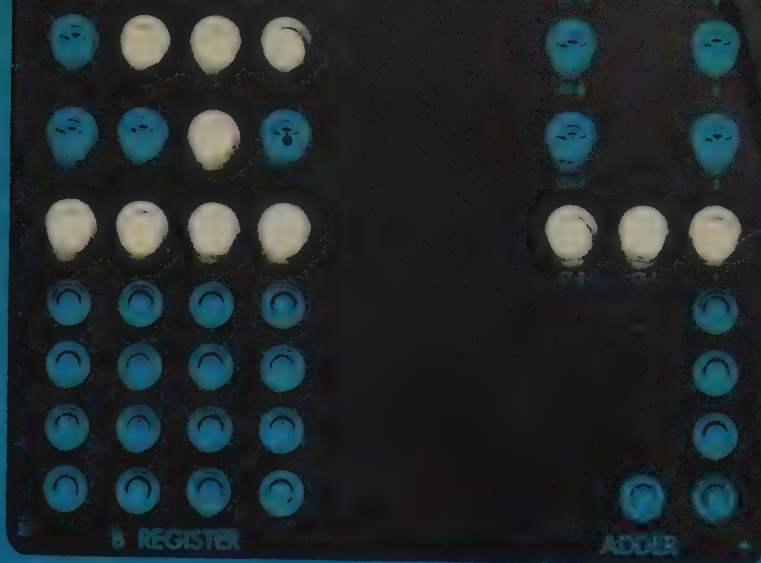
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Circle No. 20 on Reader Service Card



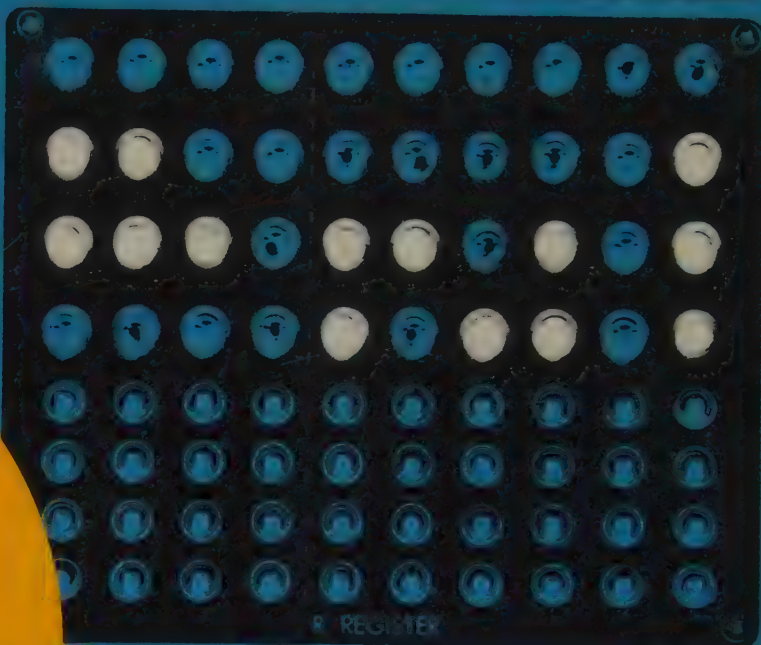
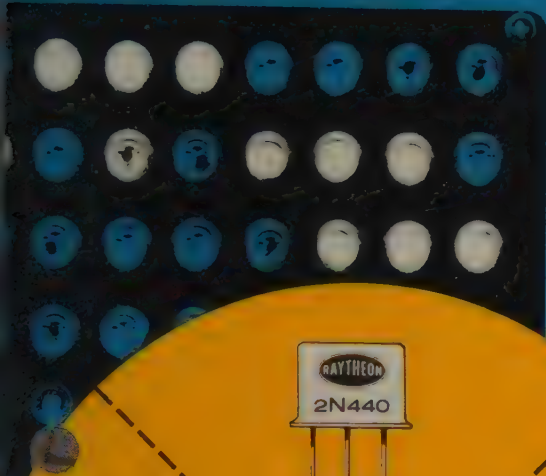


R REGISTER

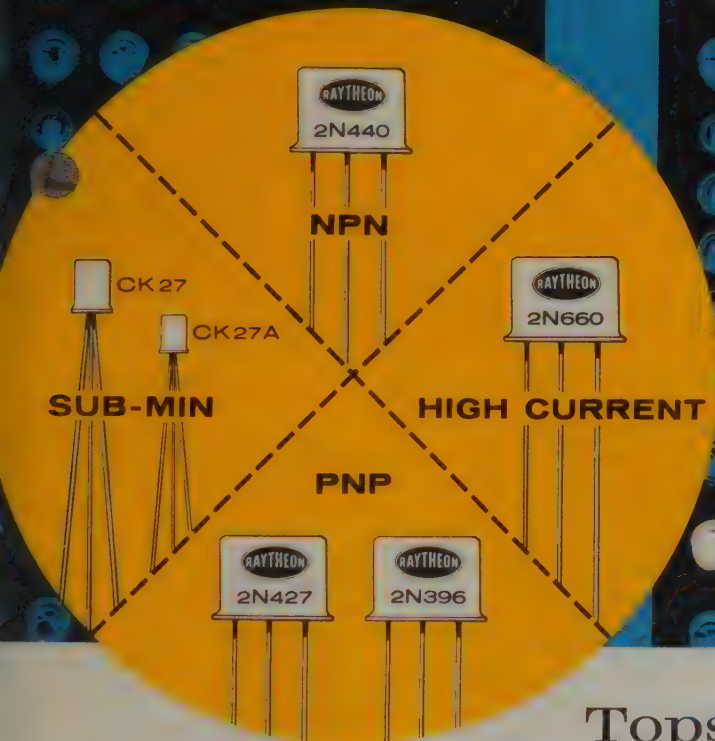


B REGISTER

ADDER



R REGISTER



## Tops for Computer Service

These Raytheon germanium transistors are top choices of computer engineers for a number of important reasons. They were developed with computer applications specifically in mind — voltage, gain, and response characteristics are optimized for this type of service. In medium frequency computer applications, these Raytheon switching transistors give you the reliability derived from years of production experience. And Raytheon's quality control program assures strict product uniformity and rigid adherence to specifications.

Result of all this is an extensive line of computer transistors that have set highest industry standards for quality and reliability. With the 2N396, which provides an internal base to case connection, Raytheon now gives you an important addition to a broad line of PNP, NPN, subminiature, and high current switching transistors. More details are given on the other side of this page. Semiconductor Division, Raytheon Company, 215 First Avenue, Needham Heights 94, Massachusetts.



# RAYTHEON SEMICONDUCTORS



# EVERYTHING YOU NEED FOR YOUR SWITCHING CIRCUITS

AVAILABLE  
IN QUANTITY...  
WITH

TRADITIONAL  
RAYTHEON  
RELIABILITY



**FOR GENERAL APPLICATION . . . THE 2N396 SERIES** PNP germanium strapped base transistors for general switching service. Temperature range  $-65^{\circ}\text{C.}$  to  $+100^{\circ}\text{C.}$  Immediate availability.

Type	$B_{VPT}$ Max. Volts	$f_{\alpha b}$ mc	$H_{FE1}$	$H_{FE2}$	$R_{Sat}$ ohms
2N395	15	4.5	40	12	2.2
2N396	20	8.0	60	20	1.3
2N397	15	12.0	80	35	1.1

**A COMPLETE HIGH CURRENT SWITCHING LINE** PNP germanium switches for 1 amp, high frequency, high gain service. Temperature range  $-65^{\circ}\text{C.}$  to  $+85^{\circ}\text{C.}$  Long a production item — excellent availability in large volume.

Type	$B_{VPT}$ Max. Volts	$f_{\alpha b}$ ave. mc	$H_{FE1}$ ave. $I_B=1\text{mA}$ $V_{CB}=-0.25\text{V}$	$H_{FE2}$ ave. $I_B=10\text{mA}$ $V_{CE}=-0.35\text{V}$	$I_C=150\text{mA}$ ohms
2N658	-16	5	50	40	0.9
2N659	-14	10	70	55	0.6
2N660	-11	15	90	65	0.45
2N661	-9	20	120	75	0.35
2N662	-11	8	30 min.	50	0.7

**IMPROVED DISSIPATION AT LOWER CURRENT VALUES** NPN germanium transistors for medium current, high frequency, high gain switching service. Temperature range  $-65^{\circ}\text{C.}$  to  $+85^{\circ}\text{C.}$  Immediate availability.

Type	$B_{VPT}$ Max. Volts	$f_{\alpha b}$ mc	$H_{FE1}$	$R_{Sat}$ ohms
2N438	25	2.5	25	3.0
2N439	20	5.0	45	3.0
2N440	15	10.0	70	3.0

**HIGH RELIABILITY PNP TRANSISTORS** germanium transistors for medium current, high frequency switching service. Temperature range  $-65^{\circ}\text{C.}$  to  $+85^{\circ}\text{C.}$  Immediate availability.

Type	$B_{VPT}$ Max. Volts	$f_{\alpha b}$ mc	$H_{FE1}$	$H_{FE2}$	$R_{Sat}$ ohms
2N425*	-30	4	30	15	2.2
2N426*	-25	6	40	18	2.2
2N427*	-20	11	55	20	1.3
2N428*	-15	17	80	30	1.1
2N404*	-24	12	See Data Sheet		

\* Available to MIL Specification

**SUB-MINIATURE TRANSISTORS** Sub-miniature transistors for medium current, high frequency, high gain switching. Temperature range  $-65^{\circ}\text{C.}$  to  $+85^{\circ}\text{C.}$  Immediate availability.

TYPE		$B_{VPT}$ Max. Volts	$f_{\alpha b}$ mc	$H_{FE1}$	$H_{FE2}$	$R_{Sat}$ ohms
.130" Dia. x .160" High	.100" Dia. x .130" High					
CK 25	CK 25A	-30	4	30	15	2.2
CK 26	CK 26A	-25	6	40	18	2.2
CK 27	CK 27A	-20	11	55	20	1.2
CK 29	CK 28A	-15	17	80	30	1.1

Your local authorized Raytheon Distributors  
carry in-stock inventories for immediate delivery.

## SEMICONDUCTOR DIVISION RAYTHEON COMPANY

SILICON AND GERMANIUM DIODES AND TRANSISTORS • SILICON RECTIFIERS • CIRCUIT-PACKS

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# HOW ACHIEVED

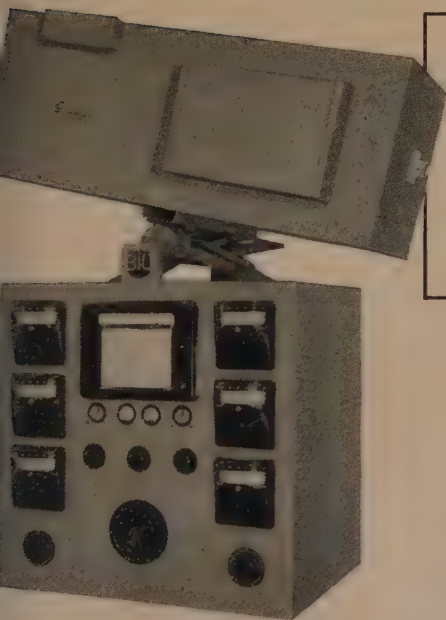


## A BREAKTHROUGH IN GAS DIFFUSION FOR THE SEMICONDUCTOR INDUSTRY

The BTU Transheat® furnaces have contributed towards great improvements in yields and reliability for continuous alloying. This was achieved by providing engineers with furnaces whose flexibility, parameters of operation, controllability and repeatability of performance enable them to lock in the optimum conditions and then maintain them continuously.

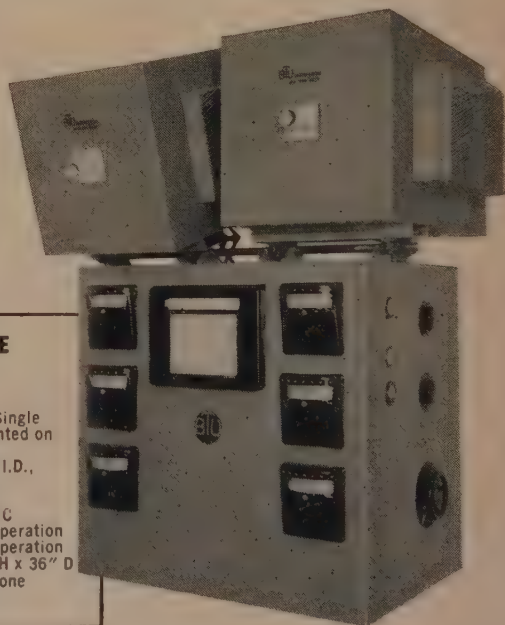
The same approach has been used for the new DZ series of gas diffusion furnaces. After determining the problems encountered by engineers working with gas diffusion, BTU designed the DZ series with complete flexibility and exclusive controls resulting in the following features:

- a true temperature flat to specified tolerances.
- stepless temperature control with controlled rectifiers.
- a tiltable furnace for best results in open end or closed tube diffusion.
- optimum insulation for stability.
- provisions to increase the number of controls for specific results.



### FOR TWO-ZONE DIFFUSION

Model D2Z  
Two Zone Furnace adjustable 25° up  
or down from horizontal  
Single Tube: 2 Zones 2 1/4" I.D.,  
approx. 72" long  
Thermal Flats: 6" to 12" long  
Maximum Temperature:  
Zone 1: 0° to 1000° ± 1°C  
Zone 2: 800° to 1400° C  
Tolerance: ± 2°C for 1300° Operation  
± 1°C for 1200° Operation



### FOR SINGLE ZONE DIFFUSION

Model: D1Z DUPLEX  
Two completely independent Single  
Zone tiltable Furnaces mounted on  
one Console.  
Two Tubes: 1 Zone each 2 1/4" I.D.,  
approx. 48" long  
Thermal Flats: up to 24" long  
Maximum Temperature: 1400° C  
Tolerance: ± 2°C for 1300° Operation  
± 1°C for 1200° Operation  
Size of Console: 48" W x 48" H x 36" D  
Model 1/2 D1Z available with one  
Furnace on same Console.



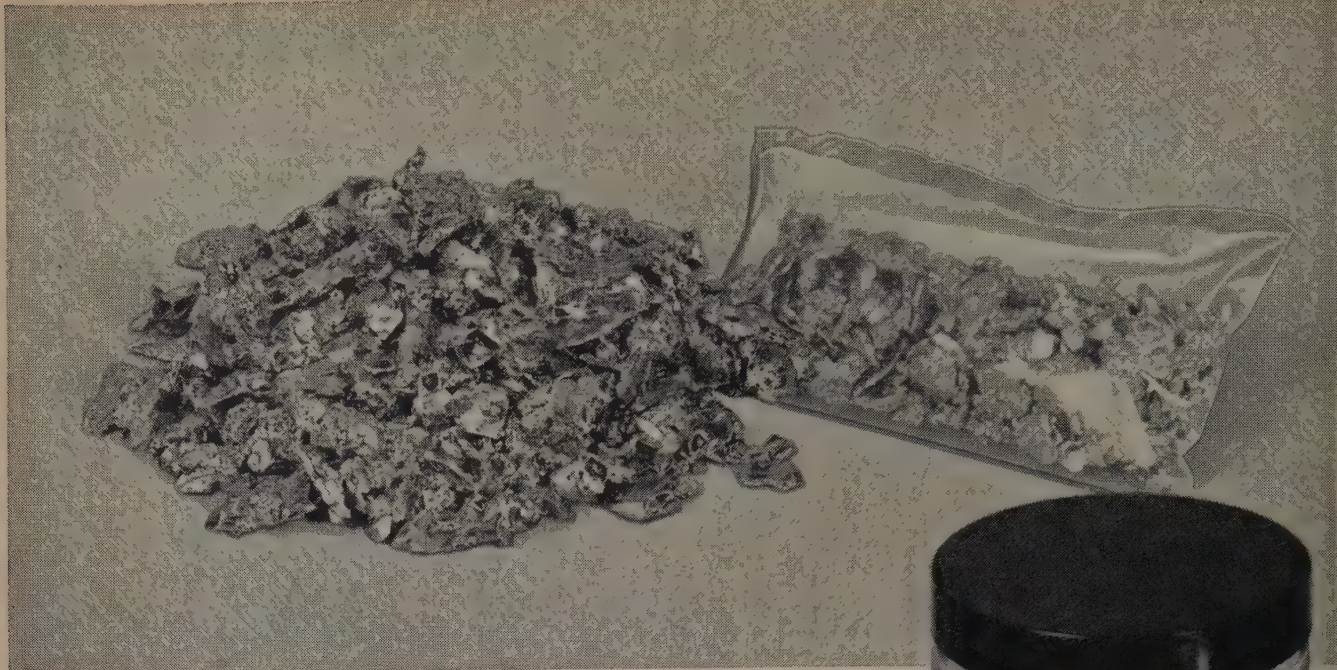
TO INCREASE YOUR YIELDS AND RELIABILITY, CONSULT...  
**ENGINEERING CORPORATION**  
**SEMICONDUCTOR PRODUCTS DEPT.**  
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WHEN IN BOSTON, YOU ARE INVITED TO VISIT OUR NEW PLANT ON ROUTE 128 . . . "ELECTRONICS HIGHWAY".

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# *ultra pure* **Gallium** *from* **EAGLE-PICHER**



New applications for Gallium are being discovered and to meet the growing demand for this rare metal, Eagle-Picher offers painstaking production and dependable supply. We offer, also, a complete line of Germanium products.

## *Eagle-Picher Rare Metals and Semiconductors*

GALLIUM, ultra pure.  
Metallic crystals, minimum purity 99.9999%  
Metallic crystals, minimum purity 99.999%  
GALLIUM SESQUIOXIDE

—also immediately available  
CADMIUM SULPHIDE

GERMANIUM DIOXIDE, minimum purity 99.999%

FIRST REDUCTION GERMANIUM METAL, minimum resistivity 5 ohm-cm.

INTRINSIC GERMANIUM METAL, minimum resistivity 40 ohm-cm.

SINGLE CRYSTAL GERMANIUM (undoped) minimum resistivity 30 ohm-cm.

SINGLE CRYSTAL GERMANIUM (doped) to customers' specified resistivity.

SPECIAL SHAPES. Intrinsic Germanium Metal for horizontal or vertical crystal growing. Wide variety in stock, other shapes furnished to customers' specifications.

SCRAP GERMANIUM PLAN. Scrap Germanium may be returned for economical reprocessing under a toll arrangement.



*Since 1843*

**THE EAGLE-PICHER COMPANY**

*Chemical Division, Dept. SP 5*

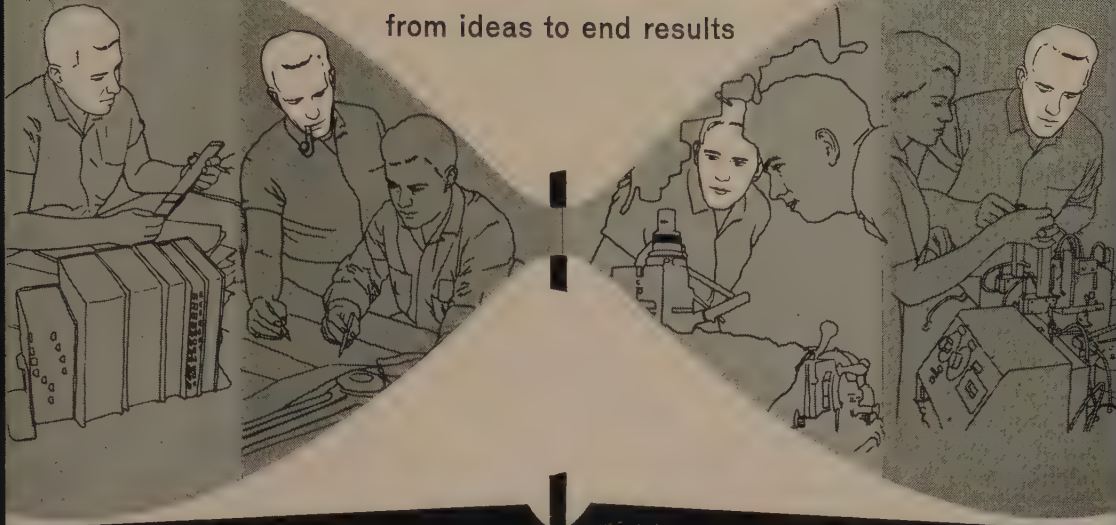
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# T/I S-C wants senior electro-mechanical engineers who prefer to pursue projects

from ideas to end results



You won't find frustrating bottlenecks in TI's immense semiconductor mechanization program. Unhampered progress toward ideal end results is assured because TI permits mechanization engineers to stay with their projects from beginning to end. Hence the remarkably short time interval between conception and production of new TI semiconductor manufacturing machines and the devices they produce.

In a broader sense your work will be a cooperative venture. For at TI S-C you are free to work even in the shop with tool makers, as with all other professional and technical specialists whose



talents will help you convert your conceptions into realities. In this ideal working climate your challenging assignments will include design, development and evaluation of mechanical, electronic and electrical mechanization equipment of widely varying types and sizes.

Requirements include a BS or MS in Mechanical or Electrical Engineering with emphasis on mechanical or servo-mechanism design and at least three years in two of the following fields: design of semiconductor test equipment, mechanized semiconductor machinery, computers, servos.

*whether applying or not, mail coupon for your copy of TIPS today and learn more about T/I Semiconductor-Components division.*

INTERVIEWS are scheduled for your area. If qualified for this position please send confidential resume immediately to C. A. BESIO, Dept. 110.

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# NEW

from

# Penfield

## For Semiconductor and Transistor Manufacture



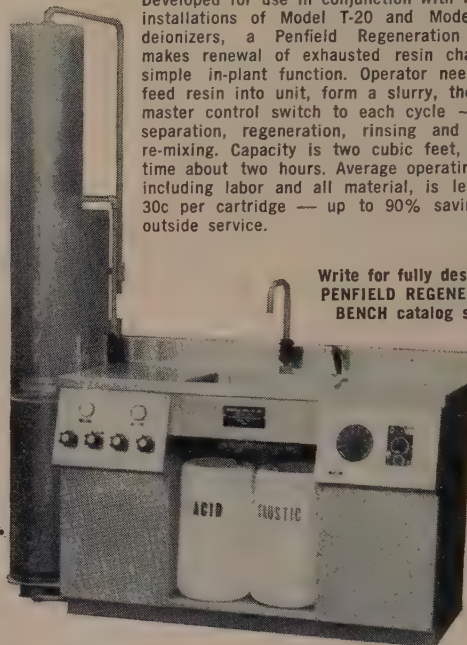
### Pressure Cartridge Deionizer Delivers 18-22 megohm Water at Point of Use

The Penfield PM-8 is a monobed deionizer that "polishes" ultra-high purity make-up and rinse water at point of use. Unique design of top distributor and collector well permits flows up to 50 GPH at less than 4 lb. pressure drop — holds exchange efficiency at 100%. Built entirely of plastic to eliminate metallic contamination. Sump is clear, allowing visual inspection of exchange resins. Cartridge unscrews by hand for easy resin replacement. Unit also can be used as cation exchanger, anion exchanger, water softener, activated carbon filter, oxygen remover or organic scavenger.

Write for fully descriptive **PENFIELD PM-8 DEIONIZER** catalog sheet.

### Resin Separator and Regenerator Saves up to 90% of Costs of Deionized Water

Developed for use in conjunction with multiple installations of Model T-20 and Model PM-8 deionizers, a Penfield Regeneration Bench makes renewal of exhausted resin charges a simple in-plant function. Operator needs only feed resin into unit, form a slurry, then turn master control switch to each cycle — resin separation, regeneration, rinsing and proper re-mixing. Capacity is two cubic feet, cycling time about two hours. Average operating cost, including labor and all material, is less than 30c per cartridge — up to 90% saving over outside service.

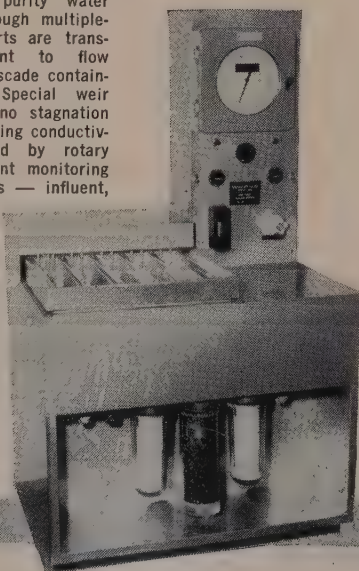


Write for fully descriptive  
**PENFIELD REGENERATION  
BENCH** catalog sheet.

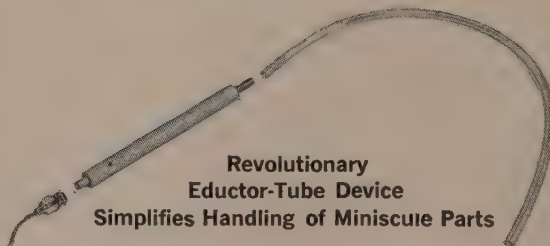
### Weir Washer "Polishes" Cascading Water to 18-22 megohms with Instant Monitoring

Integral filters and pressure-type monobed deionizers enable circulation of ultra-high purity water (18-22 megohms) through multiple-partitioned tanks. Parts are transferred counter-current to flow pattern, with each cascade containing purer water. Special weir design insures that no stagnation can occur. Direct-reading conductivity meter, controlled by rotary switch, permits instant monitoring at three check points — influent, deionizer effluent, tank effluent. Novel clip bar makes replacing heating elements simple, obviates need to empty tanks.

Write for fully  
descriptive  
**PENFIELD  
WEIR WASHER**  
catalog sheet.



### Revolutionary Eductor-Tube Device Simplifies Handling of Miniscule Parts



New Penfield Pickup makes handling of minute particles a simpler, less costly operation. Exclusive design uses air or inert nitrogen forced through a special eductor tube at 1-2 psi. Negative pressure is created at pick-up point (where standard hypodermic needles are attached) sufficient to hold germanium, silicon or other miniscule parts. To release the held particle, operator merely finger-stops an orifice in the pickup, thus creating positive pressure. Use of Penfield Pickups eliminates all foot switches, solenoids and costly vacuum equipment — also does away with troublesome plugging problems.

Write for fully descriptive **PENFIELD PICKUP** catalog sheet.

# Penfield

**MANUFACTURING CO., INC.**  
19 HIGH SCHOOL AVENUE, MERIDEN, CONN.

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SEMICONDUCTOR PRODUCTS • MAY 1960





Uniformity of Fiberglass wool is improved by close temperature control with Honeywell Model 2HCT Precision Temperature Controller, Three Mode Electr-O-Volt Controller and Magnetic Amplifier



## Temperature Control within 0.05% with new Honeywell Temperature Controller

The new Honeywell Precision Temperature Controller, series 2HCT, operates magnetic amplifiers and similar devices for control of saturable core reactor furnaces whose temperature can be measured with thermocouples.

The 2HCT consists of a null balance input circuit with manually adjusted set points and a highly stable d-c amplifier. The difference between the thermocouple signal and the set point is amplified 100,000 times to operate control circuits. Proportional band adjustment permits a decrease of sensitivity by a factor of 10.

There are 2 standard models: The 2HCT-2, which is shown above at left, and the 2HCT-3, which is designed for noble metal couples, covering temperatures from 0 to 3,000°F in 3 steps. Setting to 1/2 part in 3,000 is accomplished with a direct reading digital dial.

For applications requiring reset and derivative control functions, the 2HCT is used with a Honeywell Three Mode Electr-O-Volt Controller. Write for 2HCT Specification Sheet to Minneapolis-Honeywell, Dept. 56, Boston Division, 40 Life Street, Boston, Mass.

Model 2HCT-2, single range control unit with direct reading analog dial, is available in a wide variety of ranges for any millivoltage or thermocouple input.

- No moving parts . . . magnetic converter input
- No stray electrical pickup . . . 60 cycle rejection of greater than  $6 \times 10^9$
- Continuous automatic standardization
- Sensitive to change of less than  $1 \mu v$
- Full output power for  $12 \mu v$  input deviation from set point
- Three-mode control available using Honeywell Electr-O-Volt

# Honeywell



*First in Control*  
SINCE 1885

Circle No. 25 on Reader Service Card

75<sup>th</sup>  
PIONEERING THE FUTURE  
YEAR



# *Ultrasonic Machining calls for ultra-modern abrasive*

*... NORBIDE\* boron carbide*



The Raytheon Company, a leading manufacturer of ultrasonic machine tools, recommends NORBIDE abrasive grain as the ideal cutting agent for ultrasonic grinding applications. Ultrasonic Machine Tools convert electric current into mechanical vibrations at rates up to 25,000 cycles per second, and drive abrasive against the work with an impact force 150,000 times the abrasive's own weight. In so doing they can machine an exact counterpart of the shaped tool face into the workpiece, as shown here.

With the tremendous increase in the demand for accuracy beyond the range of conventional machining, Norton NORBIDE abrasive is a vital aid to the exceptionally high precision performance of modern ultrasonic machine tools.

NORBIDE boron carbide grain is second only to diamonds in hardness. Compared to silicon carbide grain, it provides the same degree of finish, but being less friable maintains size and speed of cut for a much longer period of time.

Ultrasonic machining is of major importance in the electronics and metalworking industries, as well as in the manufacture of intricate jewelry and fine glass and laboratory ware. Materials machined include alumina, carbon blocks, ceramics, diamondite, ferrite, germanium, granite, graphite, silicon, tungsten, mother-of-pearl, sapphire, tool steel, carbide and other alloys. Operations include shaping, slicing, trepanning, engraving, cutting of intaglios, dicing, drilling and multi-drilling. In all applications, on all materials, NORBIDE abrasive grain is essential to high precision, sharp-edge accuracy without chipping, distorting or otherwise damaging the workpiece.

Your Norton Man can give you details on how ultrasonic machining with NORBIDE abrasive may improve and economize your production. See your Norton Distributor or write to NORTON COMPANY, General Offices, Worcester 6, Mass. Plants and distributors around the world.

\*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

**NORTON**  
BORON CARBIDE

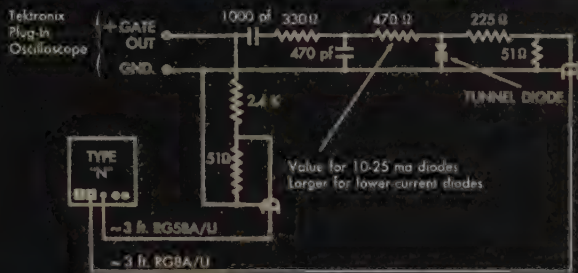
G-390

75 years of... Making better products... to make your products better

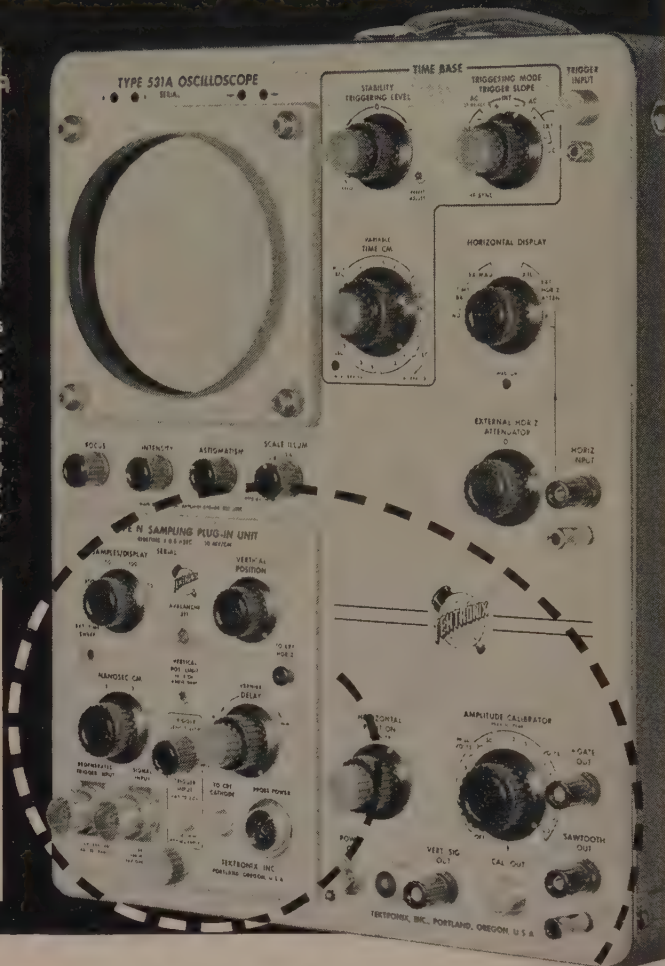
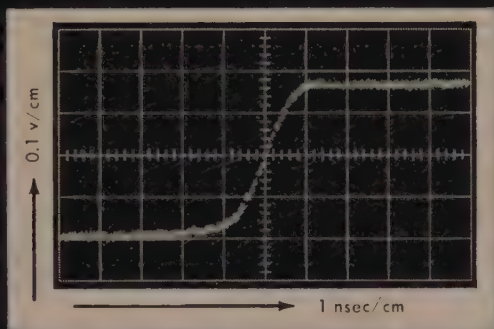
NORTON PRODUCTS: Abrasives • Grinding Wheels • Machine Tools • Refractories • Electro-Chemicals — BEHR-MANNING DIVISION: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes  
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# Tunnel Diode Switching Time Measurement with Tektronix Type N Sampling Plug-In Unit



A convenient low-cost method of testing tunnel (Esaki) diodes with nanosecond switching speeds is shown above. A Tektronix Plug-In Oscilloscope provides both the current ramp source for the tunnel diode and the pretrigger for the Type N Unit. The N Unit is set up in the usual way — however, the oscilloscope main sweep generator is allowed to free run at 1  $\mu$ sec/cm. The + GATE OUT not only triggers the N Unit but also provides a delayed current ramp with a low rate of change — which allows the tunnel diode to switch at essentially its own rate.



## NEW PULSE-SAMPLING UNIT for all Tektronix Plug-In Oscilloscopes

The new Type N Unit converts your Tektronix Plug-In Oscilloscope to a Pulse-Sampling Oscilloscope with a rise-time of 0.6 nanoseconds. Applications in which the signal source can furnish a "pretrigger", such as that shown above, require no additional equipment.

For a completely versatile Pulse-Sampling System, Tektronix also manufactures a Pulse Generator and Trigger Takeoff, a 60-nsec Delay Line, a Pretrigger Pulse Generator, and several useful accessories. Please call your Tektronix Field Engineer for complete details and, if desired, a demonstration of the Type N Unit or the complete System.

### Tektronix, Inc.

P. O. Box 500 • Beaverton, Oregon

Phone Mitchell 4-0161 • TWX—BEAV 311 • Cable: TEKTRONIX

**TEKTRONIX FIELD OFFICES:** Albuquerque, N. Mex. • Atlanta, Ga. • Baltimore (Towson, Md.) • Boston (Lexington, Mass.) • Buffalo, N.Y. • Chicago (Park Ridge, Ill.) • Cleveland, Ohio • Dallas, Texas • Dayton, Ohio • Denver, Colo. • Detroit (Lathrup Village, Mich.) • Endicott (Endwell, N.Y.) • Greensboro, N.C. • Houston, Texas • Kansas City (Mission, Kan.) • East Los Angeles, Calif. • West Los Angeles, Calif. • Minneapolis, Minn. • New York City Area (Albany, N.Y. • Stamford, Conn. • Union, N.J.) • Orlando, Fla. • Philadelphia, Pa. • Phoenix (Scottsdale, Ariz.) • San Diego, Calif. • San Francisco (Palo Alto, Calif.) • St. Petersburg, Fla. • Syracuse, N.Y. • Toronto (Willowdale, Ont.) • Canada • Washington, D.C. (Arlington, Va.)

**TEKTRONIX ENGINEERING REPRESENTATIVES:** Hawthorne Electronics; Portland, Oregon • Seattle, Washington. Tektronix is represented in twenty overseas countries by qualified engineering organizations.

In Europe please write Tektronix Inc., Victoria Ave., St. Sampsons, Guernsey C.I., for the address of the Tektronix Representative in your country.

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### Characteristics

- 0.6 nsec risetime (approximately 600 mc).
- 10 mv/cm sensitivity. (2 mv or less amplitude noise.)
- 1, 2, 5, and 10 nsec/cm equivalent sweep times (20 to 50 psec time noise).
- 50-ohm input impedance.
- 50, 100, 200, and 500 samples per display.
- Sampling rate — 50 c to 100 kc.
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# Editorial . . .

## Traveling Wave Parametric Amplifiers

The advantages of traveling wave structures, such as transmission lines or waveguides periodically loaded with parametric diodes, over structures with only one parametric diode, have been pointed out repeatedly in the literature. These consist of wide-band, non-critical large-gain, low-noise, limited reverse-gain even in the absence of a circulator. A useful contribution to the design of such amplifiers has recently appeared in the literature (C. V. Bell and G. Wade—*Trans. IRE-CT*, March 1960). In this work an infinite transmission line is considered, which is periodically loaded with the diodes. Assuming that modes of propagation exist at the signal and idler frequencies, the corresponding traveling waves must have a periodicity which is determined by the diode separation. If  $L$  is such separation,  $\beta_o$  is the phase characteristic of the unloaded line, and  $G + jB$  is the equivalent admittance of the diode at the frequency in consideration, the phase shift  $\beta_L$  and the gain of each traveling wave per diode section  $\alpha L$  are expressed as follows:

$$\begin{aligned}\cos \beta L &= \cos \beta_o L - (B/2) \sin \beta_o L \\ \alpha L &= G \sin \beta_o L / (2 \sin \beta L)\end{aligned}$$

The first relation is useful for the determination of the operating conditions and the second one for the computation of the power gain. In fact, in order to assure that the signal and the idler frequencies are in the pass band, their corresponding phases  $\phi_s$  and  $\phi_i$  must satisfy the condition  $\phi_s + \phi_i = 2 m\pi$  where  $m = 0, 1, 2, 3, \dots$ . This is equivalent to the condition that the corresponding group velocities are equal.

For large band operation the condition must be satisfied throughout the desired frequency range. This is determined graphically, plotting phase shift per section  $\beta_L$  versus normalized frequency for the given transmission line. In particular, a convenient solution is obtained selecting a bandwidth symmetrical with respect to the degeneracy point (where  $\omega_s =$

$\omega_i$ ). The condition requires, of course, that the pump frequency be selected appropriately so that gain occurs at degeneracy. The same graph is useful to check that the sidebands  $\omega_s + \omega_p$  and  $\omega_i + \omega_p$  are in stop bands, since the above frequencies, if in propagating mode, would produce a decrease of the magnitude of the negative conductance of the diodes and therefore a decrease in gain. Finally the same graph is used to assure limitation of the gain in the reverse direction, imposing a condition on the phase shift per section at the pump frequency.

The gain per section is found to be the same for the signal and the idler frequency and is expressible in terms of the amplitude of the variation of the capacitance, of the geometric mean of  $\omega_s$  and  $\omega_i$ , and of the characteristics of the transmission line.

## Semiconductor Circuit Design Awards

The Semiconductor Circuit Design Contest entries for the most outstanding Semiconductor Circuit Design Article, and for the most outstanding Nomograph related to Semiconductor Circuit Design which appeared in SEMICONDUCTOR PRODUCTS between April 1959 and March 1960 are now being evaluated by the Judges. As soon as a decision is reached appropriate announcements will be made.

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In the near future our Semiconductor Device Characteristics Charts will be expanded to include all semiconductor devices. Examples of these are electroluminescent devices, detectors, thermoelectric generators, thermistors, molecular electronic devices, and semiconductor devices that lend themselves to ferroelectric and maser applications. Manufacturers of such devices are urged to submit product parameter information for publication in our Charts.

Samuel L. Marshall



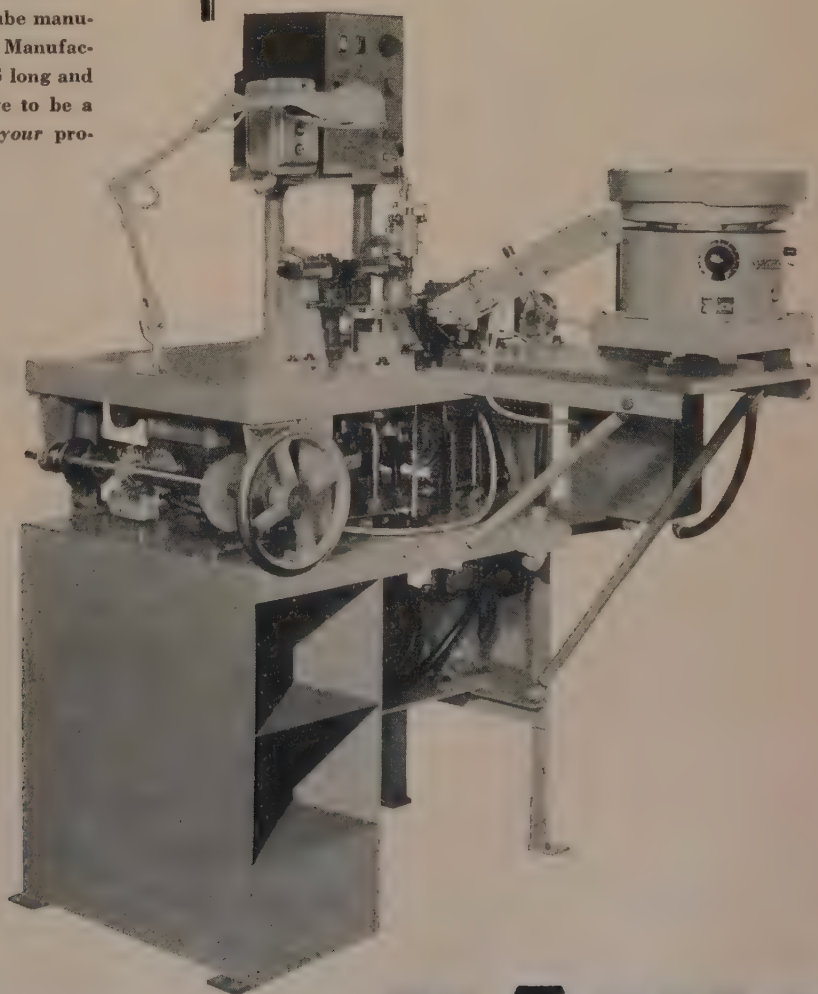
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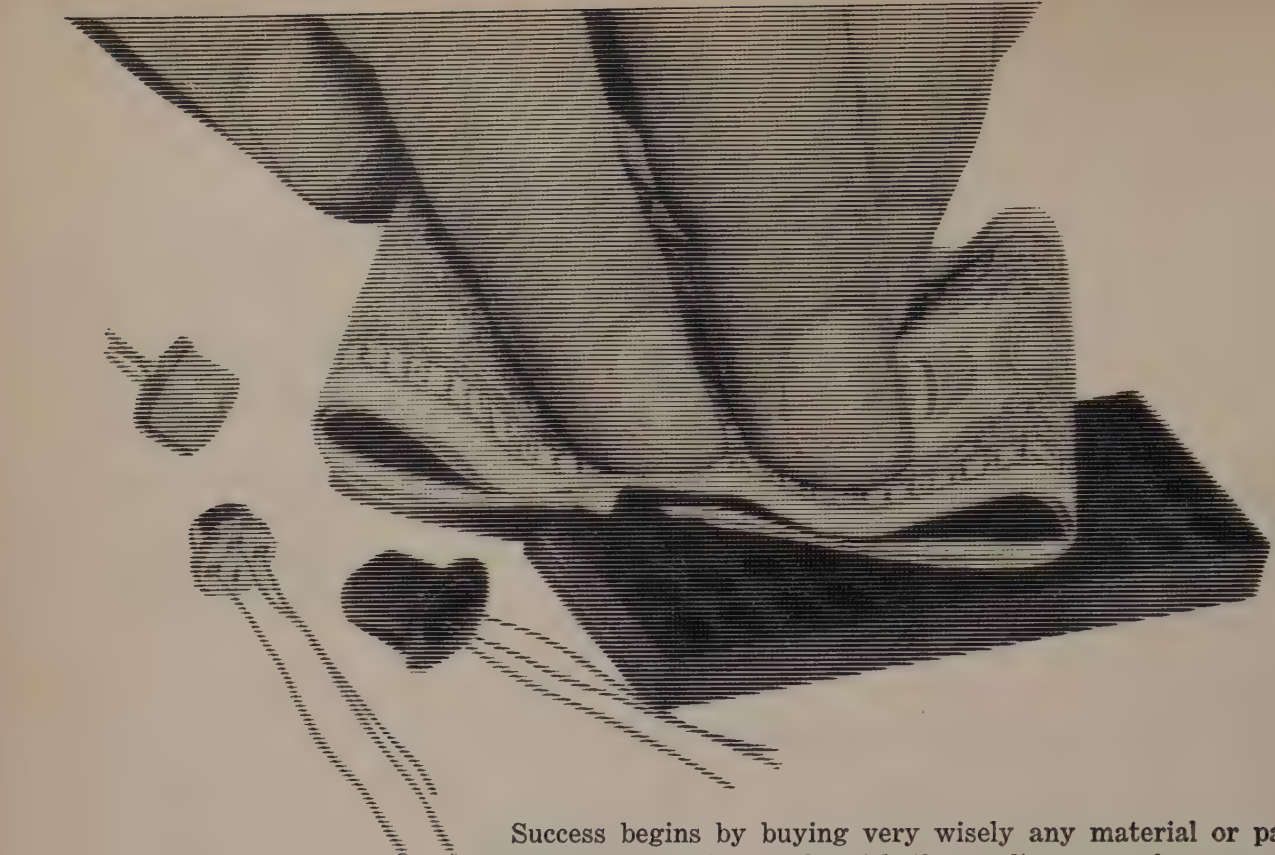


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# Esaki or Tunnel Diodes

WOLFGANG W. GÄRTNER\*

## Part 1

This survey article discusses the physical effects which produce the electrical characteristics of the tunnel diode, outlines design and construction of the devices, describes the electrical properties realized thus far, gives diagrams and design equations for *d-c* bias, oscillator, amplifier and switching circuits, and analyzes in general the potentialities of the new device.

### 1. Introduction

In October 1957, Leo Esaki,<sup>(a)</sup> research physicist at the Tokyo Tsushin, Kogyo, Limited,<sup>(b)</sup> Tokyo, Japan, submitted a one-page "Letter to the Editor" of the *Physical Review*<sup>(1)</sup> describing and explaining the current-voltage characteristic of a very narrow *p-n* junction in germanium which exhibits a negative differential resistance over a certain range of applied bias. This device has since become known as the "Esaki" or "Tunnel" diode<sup>(c)</sup> and several million dollars have been spent on its civilian and military development in the United States. Commercial availability was first announced by the General Electric Company and many other companies have followed suit. Frequent news releases in recent months have sparked widespread interest in the device. In this article, we shall describe the effect from the phenomenological and the theoretical points of view, consider the design and construction of the Esaki diode, discuss the performance of present units and summarize the basic proposed applications.

### 2. The Effect

The diode consists of an abrupt *p-n* junction between two very highly doped regions. The total thickness of the transition region is of the order of  $100 \text{ \AA} = 10^{-6} \text{ cm}$ . A typical *d-c* characteristic of such a diode built in germanium is shown by the solid line in Fig. 1. The dashed line labeled "diffusion minus drift" indicates, for comparison, the characteristic of an ordinary *p-n* junction rectifier of identical geometry but with higher resistivities in the *p* and *n* regions than those in the Esaki diode. The striking features of the tunnel diode are:

- its high reverse current, higher than the regular forward current;
- a rapid increase in forward current at very small forward voltages, followed by a drop producing a region of differential negative resistance. At still

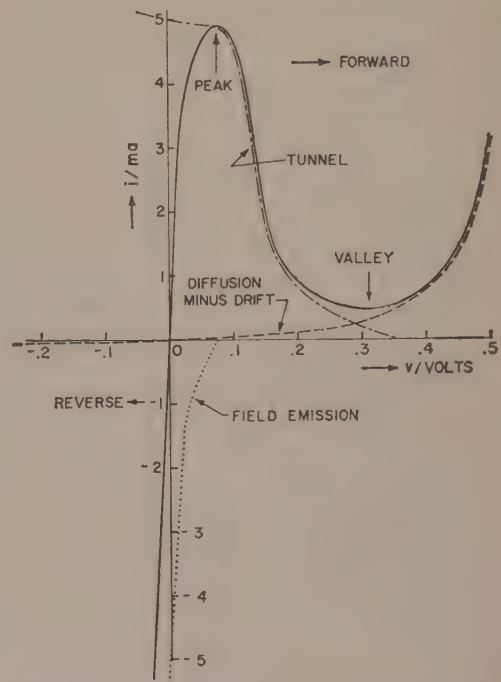


Fig. 1—Typical tunnel diode characteristic in germanium, showing contributions from the four active mechanisms.

higher voltages, the current increases again and the characteristic becomes identical with that of an ordinary *p-n* junction diode.

The voltages at the peak and valley points of the current do not vary much between diodes made of the same semiconductor. The actual values of the currents, however, may differ by orders of magnitude depending on the design—primarily the junction area (see below).

For active applications, the negative-resistance region is, of course, of primary importance. For the theoretical interpretation of the underlying mechanisms, however, a knowledge of which is required for

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(a) Dr. Esaki is presently resident consultant to the IBM Laboratories in Poughkeepsie, New York.

(b) Now known as Sony Corporation.

(c) We shall use both terms interchangeably.



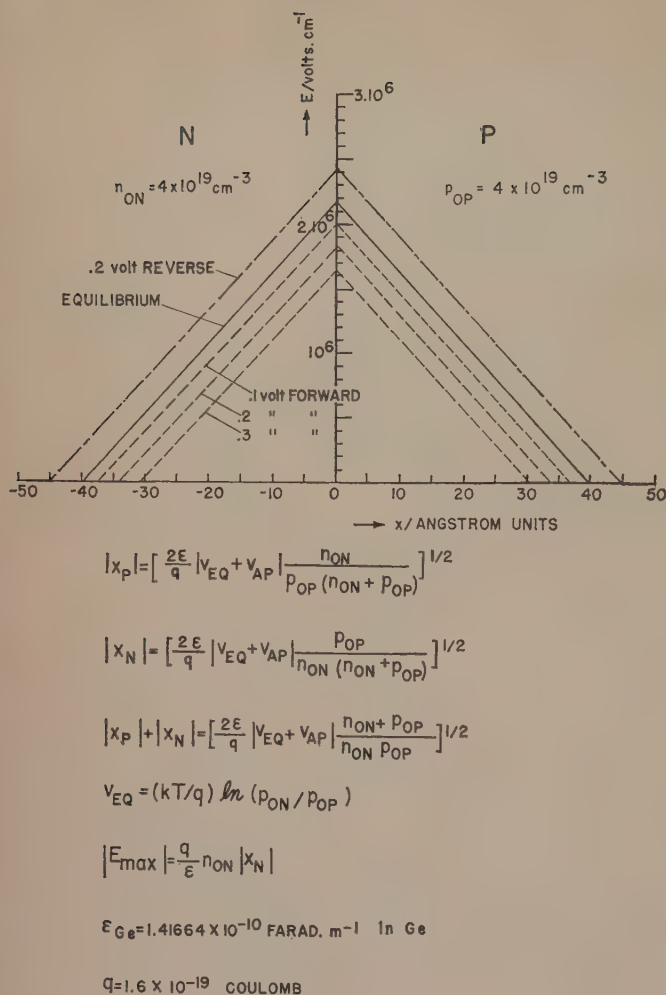


Fig. 2—Electric-field distribution in an abrupt  $p$ - $n$  junction with a majority-carrier concentration of  $4 \times 10^{19} \text{ cm}^{-3}$  on both sides, for various values of applied forward and reverse voltages,  $v_{AP}$

the formulation of a design theory, we shall consider the entire characteristic.

### 3. Mechanism

Four different carrier-transport phenomena superimpose to produce the observed  $I/V$  characteristic.

The first two of these are the electron and hole diffusion (forward direction) and drift currents (reverse direction) in the junction which cancel almost completely over a wide range of forward and reverse bias voltages. The slight disturbance of this perfect balance between the two types of current by an applied voltage produces the usual rectifier characteristic of the  $p$ - $n$  junction (dashed line in Fig. 1).

From Fig. 1 one observes that the two phenomena considered thus far account for only the high-forward bias portion of the characteristic.

An indication of the additional effects present is obtained by calculating the bias-voltage dependence of the electric field distribution in the junction and in particular the maximum field strength in the depletion layer. For an abrupt junction, Fig. 2 shows

the results for various bias voltages. One notices that the electric field in the junction is enough to produce (a) avalanche multiplication,<sup>(2)</sup> and (b) internal field emission.<sup>(3)</sup> By carrying out a careful analysis like the one given by Chynoweth and McKay,<sup>(4)</sup> one concludes that avalanche multiplication requires a certain minimum reverse voltage (a few volts) and does not take place in the immediate vicinity of the origin of the characteristics. Internal field emission, however, does occur. This third effect to contribute to the  $I/V$  characteristic of the tunnel diode consists of the excitation of a valence electron into the conduction band under the influence of a high d-c electric field. Several attempts have been made<sup>(5)</sup> to estimate the probability of this transition, and it has been found to be approximately equal to

$$P = \frac{\text{number of transitions}}{(\text{unit time}) \cdot (\text{volume in which } E \text{ prevails})} \quad (1)$$

$$= (NaqE/h) \exp \left[ -\frac{\pi^2 \sqrt{2m_{eff}} (E_G)^{3/2}}{2hqE} \right]$$

where

$N$  is the density of valence electrons,

$a$  is the lattice constant,

$E$  is the electric field strength,

$h$  is Planck's constant  $= 6.62 \times 10^{-34} \text{ joule} \cdot \text{sec (MKS)}$ ,

$q$  is the electronic charge  $= 1.6 \times 10^{-19} \text{ coul. (MKS)}$ ,

$m_{eff}$  is the effective mass of the electron, and

$E_G$  is the width of the band gap.

Substituting the following values for germanium:  $N = 1.8 \times 10^{29} \text{ m}^{-3}$ ;  $a = 5.7 \times 10^{-10} \text{ m}$ ;  $m_{eff} = 9.11 \times 10^{-31} \text{ kg}$ ;  $E_G = .67 \text{ ev} = 1.07 \times 10^{-19} \text{ watt} \cdot \text{sec}$ ; we find

$$P = 2.484 \times 10^{34} \times E \times \exp(-2.2018 \times 10^9/E). \quad (2)$$

This function is shown in Table I for electric field values which are of interest in this problem. If a high electric field,  $E$ , prevails over a distance,  $d$ , the field-emission current through a cross-sectional area,  $A$ ,

TABLE I

Number of band-to-band transitions (due to field emission) per second,  $P$ , in a given volume (in  $\text{m}^3$ ) of germanium in which a field,  $E$  (in  $\text{volts} \cdot \text{m}^{-1}$ ), prevails.

Electric field, $E$ , in $\text{volts} \cdot \text{m}^{-1}$	Number of transitions, $P$ , in $\text{sec}^{-1} \cdot \text{m}^{-3}$
$1 \times 10^7$	$5.91 \times 10^{-55}$
$2 \times 10^7$	$7.67 \times 10^{-7}$
$3 \times 10^7$	$9.95 \times 10^9$
$4 \times 10^7$	$1.23 \times 10^{18}$
$5 \times 10^7$	$9.32 \times 10^{22}$
$6 \times 10^7$	$1.72 \times 10^{26}$
$7 \times 10^7$	$3.80 \times 10^{28}$
$8 \times 10^7$	$2.21 \times 10^{30}$
$9 \times 10^7$	$5.30 \times 10^{31}$
$1 \times 10^8$	$6.80 \times 10^{32}$
$5 \times 10^8$	$1.51 \times 10^{41}$
$1 \times 10^9$	$2.74 \times 10^{43}$



perpendicular to the direction of the electric field is given by

$$i = qAdP \tag{3}$$

An electric field of  $10^6$  volt.cm<sup>-1</sup> active over a distance of 100 angstroms e.g., generates a field-emission current density in germanium at room temperature of approximately 109 amps.cm<sup>-2</sup>. If the electric field  $E$ , and therefore  $P$  are functions of  $x$  (as in all junctions), one must replace this expression by

$$i = Aq\int P \, dx \tag{4}$$

When the electric-field distribution across the junction has been determined by the methods outlined in connection with Fig. 2, one may evaluate this integral and obtain the field emission current for given impurity distribution across the junction (in particular e.g., for graded junctions as they are frequently obtained experimentally).

From Fig. 2, one observes that in these narrow junctions the electric field strength even under thermal equilibrium conditions is high enough to produce internal field emission, although in general the field-emission current is much smaller than the balanced drift and diffusion currents in the junction (which in these narrow junctions lie in the order of  $10^6$  to  $10^7$  amps.cm<sup>-2</sup>). The striking feature of the field-emission current is its extreme sensitivity to changes in the electric field (see Table I).

As the maximum electric field in the depletion layer is given by

$$\left| E_{MAX} \right| = \left[ \frac{2q}{\epsilon} \left| v_{EQ} + v_{AP} \right| \frac{n_{ON}p_{OP}}{(n_{ON} + p_{OP})} \right]^{\frac{1}{2}} \tag{5}$$

one observes that this field and, therefore, the field emission current under thermal equilibrium conditions, increases rapidly with increased impurity content on either side of the junction. Since the field also depends on the applied voltage as demonstrated in Fig. 2, it is obvious that this current will increase rapidly with reverse bias and vanish rapidly under forward bias. It has been plotted as a dotted line in Fig. 1, and is seen to account very well for the high reverse current of the tunnel diode.

The initial high forward current and the negative-resistance region, however, have not yet been explained. This portion of the characteristic requires an electron current from the  $n$  to the  $p$  side or a hole current from the  $p$  to the  $n$  side, which are high at small forward biases (most likely present under thermal equilibrium) and which drop off as the forward bias is increased. Such a current is provided by the fourth effect present in the Esaki diode, namely "tunneling."

Fig. 3 illustrates the basic principle of the quantum-mechanical "tunnel" effect: According to classical mechanics, when a particle with a total energy,  $E$ , approaches a potential barrier of height,  $U_0$ , and width,  $w$ , from the left, it will either pass the barrier if its energy is higher than the barrier ( $E > U_0$ ), or it will

TABLE II

List of Symbols Not Defined in the Text

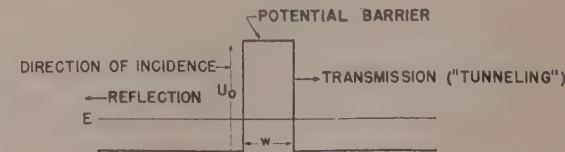
$E_{max}$ :	maximum electric field strength inside junction depletion layer
$k$ :	Boltzmann constant
$n_{ON}$ :	equilibrium electron density on $n$ side
$p_{OP}$ :	equilibrium hole density on $p$ side
$T$ :	absolute temperature
$v_{AP}$ :	applied voltage
$v_{EQ}$ :	equilibrium potential difference across junction
$v_{th}$ :	average thermal velocity of electrons
$x_N$ :	extension of the junction depletion layer into the $n$ side
$x_P$ :	extension of the junction depletion layer into the $p$ side
$\epsilon$ :	dielectric constant

be reflected by the barrier if its energy is lower, ( $E < U_0$ ). It is one of the important results of quantum mechanics, however, that even if the particle energy is lower than the height of the potential barrier, there is a certain probability that the particle penetrates the barrier, provided the latter is sufficiently thin and not too high. The tunneling probability is given in Fig. 3.<sup>(6)</sup> For  $U_0 - E = 1$  ev and  $m$  equal to the electron mass we find:

$$\begin{aligned} \text{"tunneling" probability} &\simeq 16[E/U_0 - (E/U_0)^2] \\ &\exp(-w \times 8.39 \times 10^7) \end{aligned}$$

where  $w$  is to be measured in cm. It is seen to increase exponentially with decreasing barrier width,  $w$ , and decreasing  $(U_0 - E)^{1/2}$ .

The potential barrier in the case of the tunnel diode is given by the electrostatic potential difference,  $v = v_{EQ} + v_{AP}$ , between the  $n$  and the  $p$  sides of the junction. (This is clearly seen if one considers that an electron must acquire an energy equal to  $qv$  if it wants to travel from the bottom of the conduction band on the  $n$  side to the bottom of the conduction band on the  $p$  side.) Under thermal equilibrium conditions, the Fermi level,  $E_F$ , is a constant throughout the crystal and the corresponding band picture is shown in Fig. 4a. The carrier densities are approximated by  $n_0 = N_C \exp -(E_C - E_F)/kT$  and  $p_0 = N_V \exp -(E_F - E_V)/kT$  where  $N_C$  and  $N_V$  are the "effective" densities of



$$\text{TUNNELING PROBABILITY} = \left\{ 1 + \left[ 4 \left( \frac{E}{U_0} - \frac{E^2}{U_0^2} \right) \right]^{-1} \sinh^2 \left[ w \sqrt{2m(U_0 - E)} / \hbar \right] \right\}^{-1}$$

Fig. 3—Fundamentals of the tunnel effect.



states in the conduction and valence bands respectively and are given approximately by  $2.5 \times 10^{19} (m_{\text{eff}}/m)^{3/2} \text{ cm}^{-3}$  in germanium at room temperature. From these equations one may estimate the position of the Fermi level,  $E_F$ , and for  $n_{0N} = 4 \times 10^{19} \text{ cm}^{-3}$  one finds the Fermi level 0.07 eV inside the conduction band. When a bias is applied (Figs. 4b and 4c) the quasi-Fermi levels for electrons on the  $n$  side,  $\phi_n$ , and for holes on the  $p$  side,  $\phi_p$ , retain their relative positions with respect to the band edges, but they differ by the magnitude of the applied voltage, and the energy-band scheme adjusts accordingly. One observes that for high doping where the Fermi level lies inside the bands, the upper edge of the valence band on the  $p$  side,  $E_{VP}$ , lies higher than the lower edge of the conduction band on the  $n$  side,  $E_{CN}$ , under equilibrium, reverse bias and very small forward bias. This means that between  $E_{CN}$  and  $E_{VP}$  there is a range of permissible levels with equal energies on both sides of the junction and separated by a barrier whose height is approximately equal to the band gap and whose width is approximately equal to the width of the junction depletion layer,  $|x_N| + |x_P|$ .

Approximately  $n_{0N} v_{th}/6$  electrons strike  $1 \text{ cm}^2$  of

this barrier per second ( $\approx 10^{27} \text{ cm}^{-2} \text{ sec}^{-1}$  in our numerical example) and some will tunnel through from the  $n$  to the  $p$  side. The forward tunnel current is proportional to the tunneling probability which has been seen to depend exponentially on the barrier thickness. The latter is proportional (see Fig. 2) to  $(n_{0N} + p_{0P}) / (n_{0N} p_{0P})$  and one thus realizes that the tunnel current will increase rapidly with increasing impurity content on either side of the junction. The basic model for the tunnel effect in Fig. 3 is too simple to yield a quantitative description of the observed phenomenon. Some of the complications are listed in the following:

a. The exact shape of the potential barrier is not known but has a rather pronounced effect on the tunneling probability.

b. In a crystal we do not have a continuous range of permissible energy levels on the two sides of the barrier as assumed in the simple model of Fig. 3. Rather, we are concerned with two different ranges of discrete levels, the bands, and transitions between these are subject to additional energy and momentum conservation rules. Further difficulties arise from the complicated structure of the band edges involved in the transitions.

c. Serious and not fully known modifications occur in the band scheme for highly degenerate material and high electric fields. Similarly, the position of the impurity levels near the junction region is uncertain but they contribute to the transition probability.

d. In a number of semiconductors including germanium and silicon (but not, for example, GaAs, GaSb) tunneling involves interactions with phonons.<sup>(7)</sup>

Under an applied forward bias the barrier becomes thinner which should lead to an increased tunnel current. Actually, however, the opposite is the case: Under forward bias the overlapping range of permissible energy levels on the two sides of the junction (between  $E_{CN}$  and  $E_{VP}$  in Fig. 4) drops to zero and the bands begin to separate. The consequences of this shift in the relative position of the bands have not yet been analyzed satisfactorily, but it is known to cause a rapid decrease in the number of transitions and thus in the forward tunnel current, which vanishes at approximately 0.3 volts forward bias in germanium. The "forward-tunnel" current contribution to the  $d$ -c characteristics of the Esaki diode has been plotted as a dash-dot line in Fig. 1, making the explanation of the  $I/V$  curve complete. Actually there is usually an additional contribution to the current at the valley point which is of uncertain origin and has been termed "excess current." It has been reduced by improved manufacturing techniques.

One observes that the magnitude of the forward tunnel current under equilibrium conditions determines the peak current value and largely also the magnitude of the negative conductance, which, therefore, increase with increased impurity content.

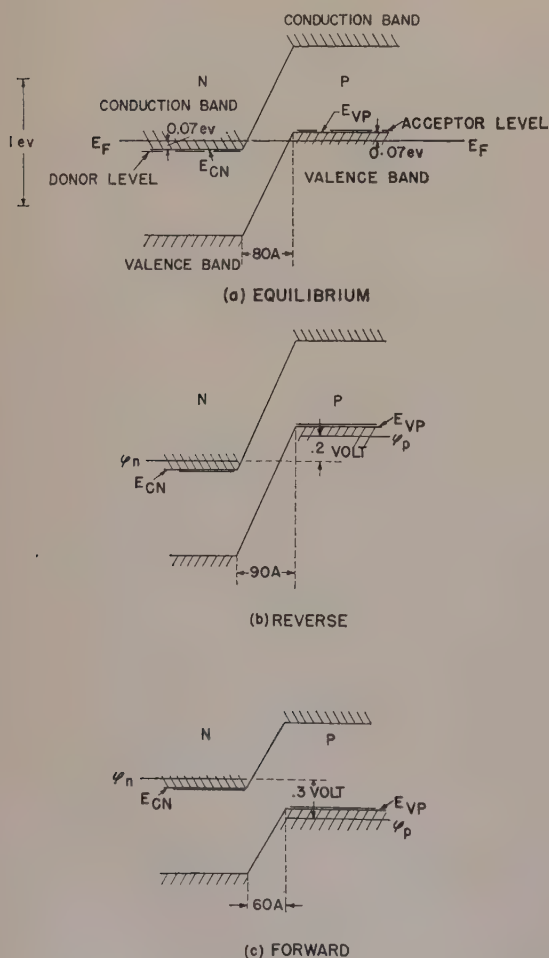


Fig. 4—Energy-band diagram in germanium tunnel diode with an impurity content of  $4 \times 10^{19} \text{ cm}^{-3}$  on both sides of the junction. (A) Thermal equilibrium. (B) 0.2 volts reverse voltage. (C) 0.3 volts forward voltage.



#### 4. Design, Construction and Characteristics<sup>(8)</sup>

The magnitude of the negative conductance,  $-1/R = -G$ , of the diode is proportional to the junction area and increases rapidly with increased impurity content on either side of the junction, as has been explained earlier.

For a plane-parallel abrupt junction the capacitance is given by

$$C = \frac{\epsilon A}{|x_N| + |x_P|} = A \left[ \frac{\epsilon q}{2} \frac{1}{|v_{EQ} + v_{AP}|} \frac{n_{ON} p_{OP}}{(n_{ON} + p_{OP})} \right]^{\frac{1}{2}} \quad (6)$$

It increases proportionally with the junction area and approximately with the square root of the impurity density. Thus small capacitance and high negative conductance are seen to be two conflicting design requirements between which a compromise must be reached.

Eq. 6 indicates a non-linear increase of  $C$  with forward bias which is also observed in ordinary  $p$ - $n$  junction diodes. In the negative-resistance region, however, the capacitance, although non-linear, does not seem to follow the predicted voltage dependence.<sup>(9)</sup> Because of the high shunt conductance exact measurements in this range are very difficult.

In a junction with  $4 \times 10^{19} \text{ cm}^{-3}$  impurities on each side, the capacitance will lie between 1.5 and 3  $\mu\text{f}\cdot\text{cm}^{-2}$  depending on the applied bias. The tunnel diode has the highest capacitance per unit area among all junction devices.

The internal series resistance of the diode,  $r$ , co-determines the frequency response and must be made as small as possible. This is achieved by a very thin and highly doped semiconductor and good ohmic contacts.

For high power output the junction area should be made as large as the capacitance requirements permit.

Since the capacitance of the tunnel diode is so large, the series inductance in the circuit must be kept extremely small if high-frequency operation is to be achieved. Typically, for 1 Kmc operation, the series inductance must be less than 0.1  $\mu\text{H}$ . Sommers<sup>(10)</sup> describes a microstrip mount for the diode which fulfills this requirement. In other instances the diode has been mounted directly across the ends of a strip line or a coaxial cable.

The common technique for constructing the diode consists of alloying a metal pellet onto a wafer of highly doped semiconductor material. Sommers<sup>(10)</sup> mentions a 3 mil dot of  $\text{In} + 0.5\% \text{ Ga} + 0.5\% \text{ Zn}$  alloyed into  $10^{-3} \text{ ohm}\cdot\text{cm}$  germanium doped with  $2 \times 10^{19} \text{ cm}^{-3}$  arsenic impurities.<sup>(11)</sup>

The simplicity of the structure indicates that the eventual price of the unit will be quite low. Fig. 5 shows a microphotographic sectional view of a tunnel diode.

The positions of the peak and valley points on the  $I/V$  characteristics of germanium diodes lie at approximately 70 and 300  $\text{mV}$  respectively. Depending on the junction area and doping, peak current values lie

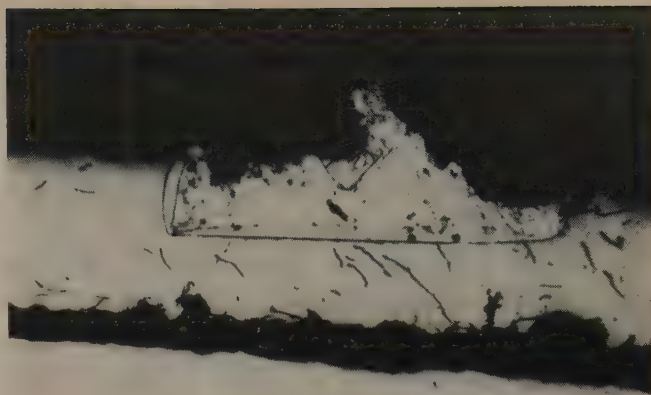


Fig. 5—Microphotographic cross section of silicon tunnel diode shows original  $n^+$ -type silicon wafer mounted on a metal plate and on the top surface a regrown  $p^+$ -type region along with the alloy from which the  $p^+$  material was grown. Magnification 250x. (Courtesy of N. Holonyak, Jr., and I. A. Lesk, G.E., Syracuse, N. Y.)

between fractions of a milliamperere and amperes. The best peak-to-valley current ratios run about 15 to 1.

In addition to germanium, tunnel diodes have been built of Si, GaAs, GaSb and InSb (the last operated at 78°K and below). Among these, gallium arsenide diodes (scheduled to be marketed by GE in the summer of 1960) appear the most promising with peak-to-valley current ratios of 60 to 1 and voltage swings to 1.2 v.

Negative resistances as low as  $-1 \text{ ohm}$  with a junction area as small as  $10^{-5} \text{ cm}^2$  ( $C \approx 50 \mu\text{f}$ ) have been achieved by extremely high doping. Output powers range from watts at very low frequencies to microwatts in the kilomegacycle region. Diodes have been built which oscillate at a fundamental frequency of a few Kmc and which switch in 2  $\mu\text{sec}$ . Noise characteristics are mentioned later under "Applications."

The range of permissible operating temperatures for the tunnel diode is most likely greater than that for any other junction device made of the same material because the transition to intrinsic conduction occurs at very high temperatures due to the high impurity content. In addition, the resistance to nuclear radiation is also expected to be very high because the dominant mechanisms are to a first order independent of bulk and surface recombination. Fig. 6 illustrates the nuclear and temperature resistance of a germanium tunnel diode. It must be pointed out, however, that even small changes in the characteristics due to temperature or other environmental conditions have a pronounced effect on small-signal performance as will become apparent below. The wide range of permissible operating temperatures unfortunately does not result in temperature stability of circuit performance (a characteristic possessed by many other semiconductor devices). The wider-bandgap materials seem to be superior in this latter respect, as one would expect.



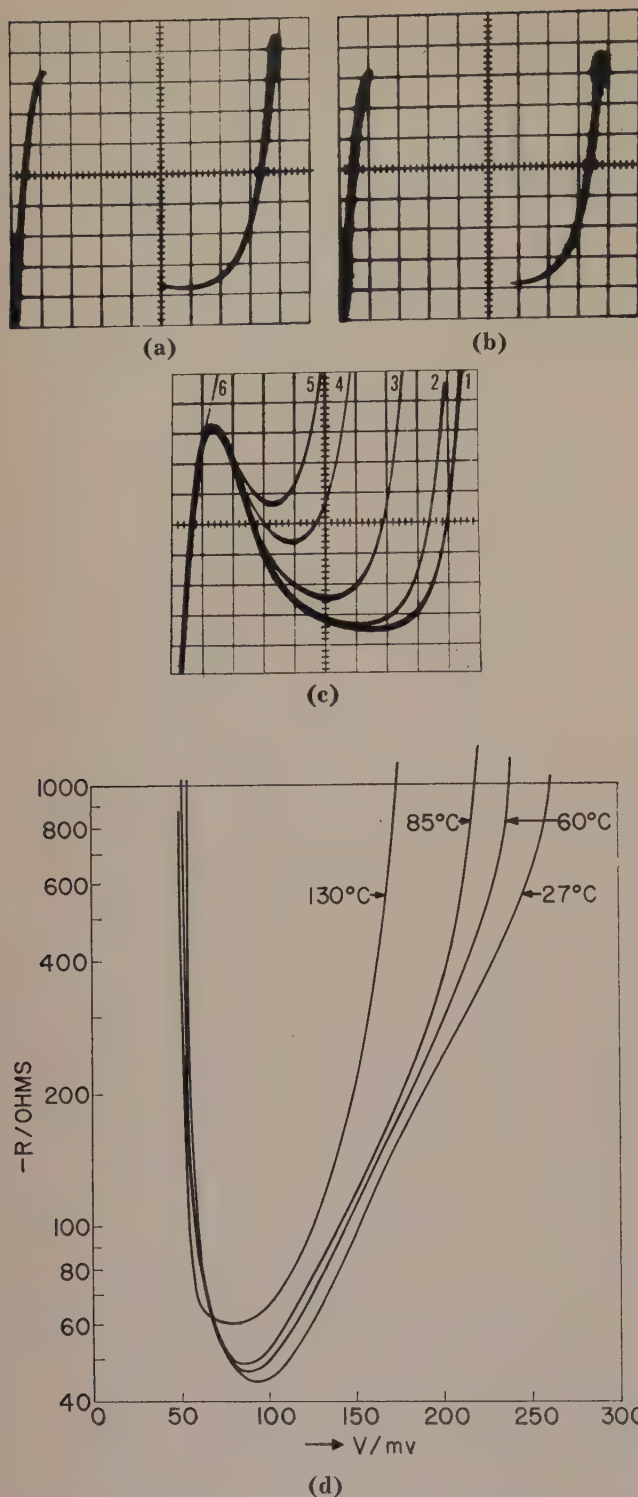


Fig. 6—Germanium tunnel-diode characteristics under nuclear bombardment and as a function of ambient temperature. (a) Forward characteristic before, and (b) after  $10^{13}$  n.v.t. in the Godiva reactor (Measurements taken by F. Gordon, USASRDL, Fort Monmouth, N. J.) (c) Forward characteristic at (1) 26°C, (2) 50°C, (3) 100°C, (4) 160°C, (5) 200°C. Peak current is approximately 3 ma. (Measurements taken by M. Schuller, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.) (d) Differential negative resistance of germanium tunnel diode at various temperatures measured versus operating point by a bridge method (signal amplitude approximately 6 mv). The measurements were taken by M. Schuller at USASRDL.

## Equivalent Circuit

The customary equivalent circuit for the tunnel diode is shown in Fig. 7a. Since the negative resistance arises from an extremely fast process, the low-frequency  $I/V$  characteristic holds up to microwave frequencies and the only frequency dependence in the diode is introduced through its junction capacitance,  $C$ .

Depending on the package used, one may have to include its series (lead) inductance,  $L_p$ , into the equivalent circuit.

Fig. 7b shows some of the symbols which have been proposed for the tunnel diode.

## 5. Applications

### D-C Bias Circuit

To obtain a stable  $d$ -c operating point in the negative-resistance region, one may use a supply circuit such as the one shown in Fig. 8b with the supply voltage,  $V_B$ , and the internal resistance of the source,  $R_o$ , chosen such that the  $d$ -c load line intersects the diode characteristics at only one point,  $(I_o, V_o)$ . The necessary conditions are shown in the figure. After the values for  $-R$  and  $V_1$  of the diode have been determined from a plot of the characteristics, and a desired operating point  $(I_o, V_o)$  has been chosen, the equation given in the figure is used to find  $R_o$  and  $V_B$ .  $R_o$  is the internal resistance of the source as it presents itself at the two terminals. In certain cases it must be very low due to the condition  $R_o < R$ , and it may then be realized by a circuit as shown in Fig. 9. It has the added advantage that the necessary supply voltage,  $V_B$ , which usually lies at a few tenths of a volt, may be stepped down from any convenient source. Series inductances in the supply circuit must be avoided to prevent unwanted oscillations. The circuit of Fig. 9 has the property that any inductance,  $L'$ , in the voltage supply, appears at the terminals of the source reduced by a factor of approximately  $(R'/R'')^2$ . It may, therefore, be used to display the diode characteristics on an oscilloscope using a transformer (with inductance  $L$ ) as the sweep supply (see Fig. 10). Fig. 11c shows how one may completely separate the  $d$ -c supply circuit from the  $a$ -c path by shorting it with a very large capacitance  $C'$ .

### A-C Circuits

Fig. 11 shows the two basic configurations for negative-resistance oscillator circuits. We shall first consider the circuit in Fig. 11a. We find that:

Diode

$$i = vY/(1 + rY) \quad (7)$$

where

$$Y = -1/R + j\omega C \quad (8)$$



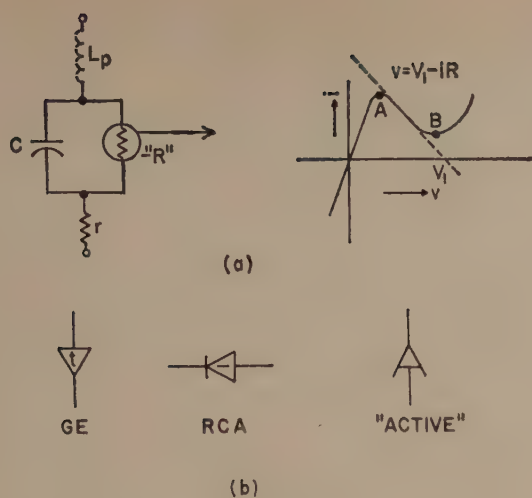


Fig. 7—(a) Equivalent circuit and low-frequency characteristic of the tunnel diode. In the negative-resistance region between peak and valley points, "A" and "B," the curve may be approximated by a straight line with slope  $-R$ .  $C$  is the junction capacitance,  $r$  is the equivalent series loss resistance. (b) Symbols proposed for the Esaki diode: General Electric, "t" for "tunnel"; RCA, "—" for "Negative resistance"; 3rd possibility, "A" for "Active" diode.

### External Circuitry

$$i = -v/Z \quad (9)$$

where

$$Z = R_L + j\omega L \quad (10)$$

Setting the two expressions for the current,  $i$ , equal to each other, we find that oscillations may occur ( $v \neq 0$ ) only if

$$-1/Z = Y/(1 + rY) \quad (11)$$

The imaginary part of this equation yields for the frequency of oscillation

$$\omega^2 = 1/(LC) - 1/(RC)^2 \quad (12)$$

and the real part yields for the starting condition

$$R_L = -r + R/(1 + \omega^2 R^2 C^2) \quad (13)$$

One notices that  $R_L < R$ , otherwise no oscillations would occur. At the same time, the condition for a stable d-c operating point in the negative-resistance region would be violated. From Eq. 13 it is apparent that the highest frequency of oscillation is achieved for  $R_L = 0$ , namely

$$\omega_{max} = \frac{1}{C} \left[ \frac{1 - r/R}{Rr} \right]^{1/2} \simeq \frac{1}{C \sqrt{hr}} \quad (14)$$

One observes that for high frequency of operation,  $C$ ,  $R$  and  $r$  of the diode should be as small as possible. To achieve oscillations at lower frequencies, it is more advantageous to add an auxiliary capacitance,  $C_a$ , (see Fig. 11) rather than increase the inductance,  $L$ , because due to the reduced  $L/C$  ratio of the resonant circuit, the output wave form is more sinusoidal. The

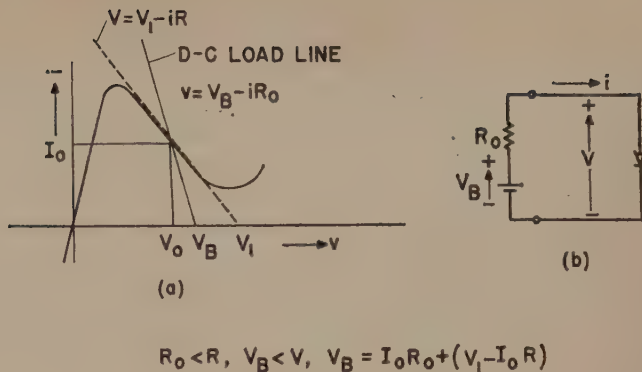


Fig. 8—Bias arrangement to obtain stable d-c operating point in the negative resistance region.

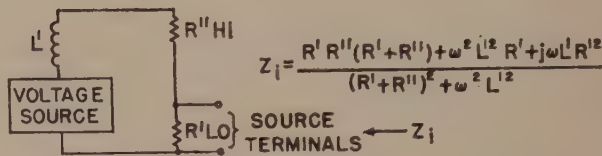


Fig. 9—D-C supply with low internal resistance and low internal inductance.

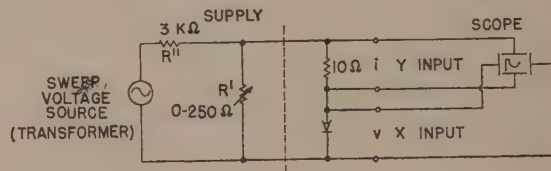


Fig. 10—Circuit arrangement for oscilloscope display of diode characteristics. (Courtesy M. Schuller, USASRD, Fort Monmouth, N. J.)

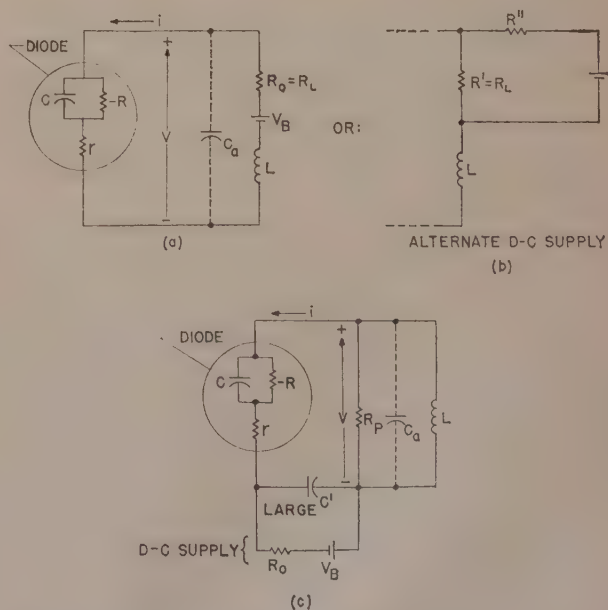


Fig. 11—Basic negative-resistance oscillator circuits.



frequency of oscillation may then be calculated by replacing  $C$  by  $C + C_a$  in the formulae (and neglecting the effect of  $r$ ).

In the circuit of Fig. 11c, we have for the external circuitry

$$i = -[1/R_P + 1/(j\omega L)] v \quad (15)$$

and one finds in an analogous way

$$\begin{aligned} \omega^2 &= \frac{1}{CL} \frac{(1 - r/R)}{(1 + r/R_P)} = \frac{(1 - r/R)^2}{LC - r^2 C^2} \\ &= \frac{(1 - r/R) [1 + (r - R)/R_P]}{C^2 r R (1 + r/R_P)} \quad (16) \end{aligned}$$

and

$$R_P = [(1 - r/R)^2 + r^2 \omega^2 C^2] / [(1 - r/R)/R - r \omega^2 C^2] \quad (17)$$

$$L = \frac{1}{\omega^2 C} \frac{(1 - r/R)}{(1 + r/R_P)} = (1 - r/R)^2 / (\omega^2 C) + r^2 C \quad (18)$$

One observes that stable oscillations are achieved only for

$$R_P > R \quad (19)$$

This condition is not in conflict with any requirement on the  $d$ -c supply circuit which is entirely separated from the  $a$ -c path. If it is not satisfied oscillations will occur and the circuit may be operated as an amplifier as explained below. As  $R_P \rightarrow \infty$  one reaches, of course, the same maximum frequency of operation as given by Eq. 14. Sinusoidal oscillations at lower frequencies are again best achieved by adding an auxiliary capacitance,  $C_a$ .

(To be continued)

So far we have derived conditions for oscillation and expressions for the frequency of tunnel diode oscillators. To complete the circuit-design theory, we would have to add a discussion of amplitude limitation, power output and distortion. These, however, are more advanced subjects which require the numerical or graphical solution of differential equations<sup>(12)</sup> and exceed the scope of this article. As the amplitude increases and the instantaneous operating point swings deeper into the positive-resistance regions adjacent to the negative-resistance range, one finds the transition to the relaxation oscillator which can here be analyzed in exact form employing advanced circuit techniques.<sup>(12)</sup>

As the frequency of oscillation depends on the capacitance,  $C$ , of the tunnel diode as well as on its differential negative resistance,  $-R$ , a tunnel-diode oscillator may be tuned by changing its operating point. The non-linearity of the capacitance may also be used for frequency conversion and mixing while the negative resistance of the diode is simultaneously used for oscillation and amplification.<sup>(13)</sup>

Since the voltage swing of the device is limited to approximately  $0.45v$  in germanium,  $0.75v$  in silicon and  $1.2v$  in gallium arsenide, higher output voltages must be achieved by transformation which, however, is difficult because inductance values must be kept very low. At high frequencies the permissible junction area and thus the current are limited by capacitance requirements so that output power drops with increasing frequency. Because of the small  $d$ -c power requirements on the other hand, tunnel diode oscillators operate with high efficiency.

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# The Hall Effect

## Applications in Electrical Measurements

L. E. FAY III\*

The Hall effect, used for many years as a tool in experimental physics has recently been noticed by electrical engineers who were in need of a device having some of the characteristics of the Hall effect. Modern research in materials and geometrical configuration has developed devices of good enough efficiency to begin to be useful in engineering applications. This article is a review of most of the simple applications of the Hall effect covering the elementary electrical circuit theory upon which these applications are based.

THE HALL EFFECT, known to physicists since 1879 has, in recent years, been given considerable attention by electronic engineers because of certain very interesting properties.

The Hall effect<sup>(1)</sup> is a galvanomagnetic effect which is the solid state analogue to the magnetic deflection of the electron beam in a television tube. An electric current,  $I$ , is passed through a crystal in a direction perpendicular to a magnetic field,  $B$ . The crystal is usually a thin rectangular plate oriented as in *Fig. 1*. The current carriers, either electrons or holes, are deflected according to the usual left hand rule in a direction mutually perpendicular to both  $I$  and  $B$ . Some of the deflected carriers pile up at the edges of the crystal and generate an electric field which opposes the magnetic deflection. When the electric field equals the magnetic force, an equilibrium voltage is established across the edges of the crystal, which voltage is described as

$$V_H = \frac{10^{-8} R_H I_s B}{t}$$

where  $t$  is the thickness of the crystal in cm,  $I_s$  in amperes and  $B$  in gauss are as previously described, and  $R_H$ , the Hall coefficient measured in  $\text{cm}^3/\text{coulomb}$  is a proportionality factor which depends upon bulk properties of the crystal such as resistivity and carrier mobility. Typical values of  $R_H$  are shown in Table I. There are correction factors for crystal geometry and size of voltage lead contacts. It has been noticed by the author that for large soldered voltage contacts, the output voltage for crystals cut from the same or comparable bulk material ( $n$ -type germanium, about three ohm-cm), varied directly as the resistance between the leads, while the short circuit current remained essentially constant. For any particular crystal, an empirical correction factor may be obtained or the corrections just absorbed into  $R_H$ . A crystal with a large  $R_H$  is desired so a semiconductor is usually used. Commonly used materials are silicon, germanium, indium antimonide, and indium arsenide.<sup>(2,3,4)</sup>

From the foregoing considerations, it is seen that the Hall voltage is proportional to the product of a driving current and a magnetic field. In an electromagnet, the

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Table I

Material	$R_H$ (typical) $\frac{\text{cm}^3}{q}$
Germanium	$2 \times 10^3$
Silicon	$15 \times 10^3$
Indium Antimonide	$0.6 \times 10^3$
Indium Arsenide	$0.8 \times 10^3$

effective field at the crystal can be varied in three independent ways: (1) by changing the magnet current; (2) by changing the orientation of the crystal in the field; (3) by changing the distance from the crystal to the magnet. Thus the experimenter has at his control a voltage which is proportional to the product of up to four independent variables. With so many degrees of freedom, a large number of interesting applications can be made.

### Simple Applications

Perhaps the simplest and most straightforward appli-

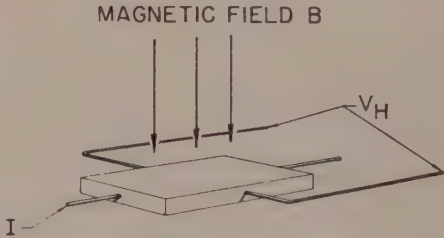


Fig. 1—The Hall effect.

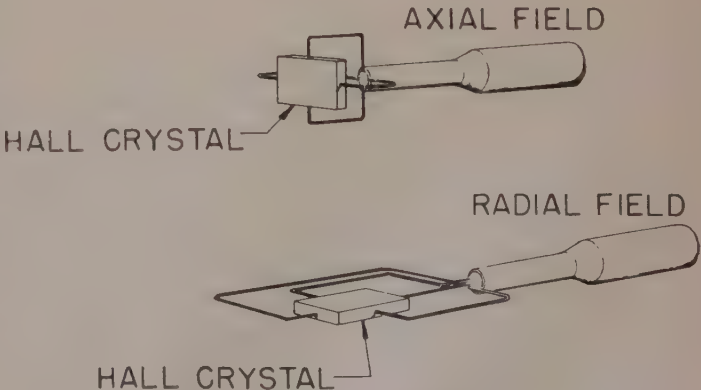


Fig. 2—Gaussmeter probes.



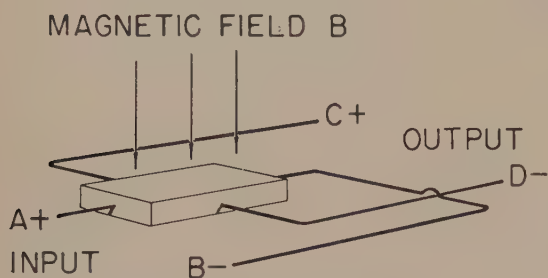
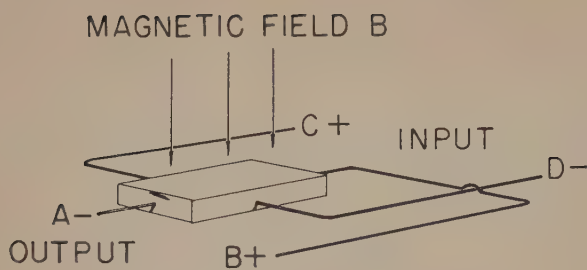


Fig. 3—Hall effect gyrator.

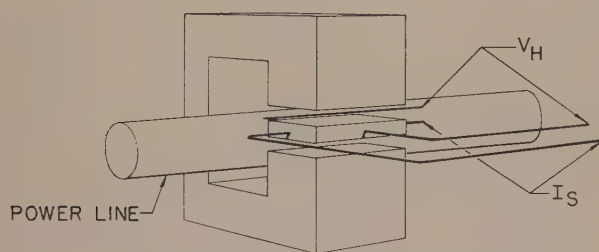


Fig. 4—Hall effect ammeter.

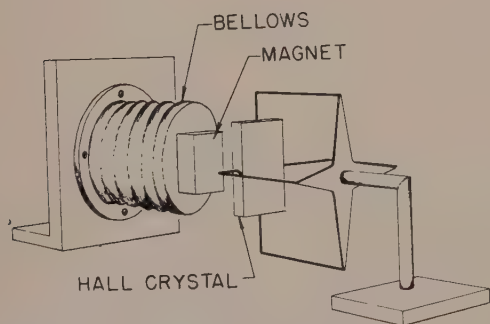


Fig. 5—Hall effect distance indicator.

cation is a gaussmeter. The crystal is mounted on a probe so that it may be placed perpendicular to the field to be measured (Fig. 2) It is calibrated at some known field for one or more currents depending upon the range of the output meter. Although theoretically a one-point calibration is sufficient, calibration at several fields will reduce errors due to nonlinearity introduced by high fields or loading of the crystal. When measuring a field, the crystal should be rotated slightly to get maximum output for that location. This assures that the crystal is perpendicular to the field.

The Hall effect may be used as a gyrator<sup>(5)</sup> (Fig. 3),

an interesting example of a nonreciprocal circuit. A nonreciprocal device is defined as one which will pass information in two directions through the device, (output and input terminals may be interchanged) but operates upon the information in a different manner in each of the two directions. The best known gyrators are the ferrites used to rotate the plane of polarization of a wave in a waveguide. The Hall effect gyrator reverses the polarity of a signal when the input and output are interchanged. If a direct current is driven between A and B so that A is positive, conditions of magnetic field and carrier-type can be adjusted so that of the output voltage measured between C and D, C is the positive terminal. If C and D are now made the current or input leads, with terminal C positive, terminal A will be the negative terminal of the output voltage between A and B.

Another simple application is in an ammeter, either a-c or d-c, which is not a series element in the circuit (Fig. 4). The current in the wire induces in the yoke a magnetic field proportional to the current. The Hall voltage at constant crystal current is proportional to the magnetic field and thus to the field current. This device will work best at very high currents where conventional ammeters are difficult to calibrate and use.

The fact that the field of a magnetic pole follows the inverse square law<sup>(6)</sup> (Fig. 5) can be applied to a Hall effect distance meter. Either the crystal or the magnet can be mounted on a movable rod or bellows with the other element fixed. Motion of the rod or bellows would be detectable in the variations of  $V_H$ .

If the crystal is mounted on a rotating shaft in a uniform magnetic field in such a way that electrical contacts are made through slip rings or long wires to allow for several revolutions of the crystal, the number of applications increases greatly. The same result is obtained if the crystal is fixed and the magnet rotated. The effective magnetic field intercepted by the crystal varies sinusoidally with  $\theta$ , the angle of rotation of the crystal so that  $B_{eff} = B_{max} \sin \theta$  or  $B_{eff} = B_{max} \cos \theta$  depending upon the choice of zero point. (Fig. 6).

The obvious application of this is a low frequency sine wave generator. If some hi-fi fan is boasting too much about the bass response of his system, just fasten a Hall crystal to the second hand shaft of a clock and let him try one cycle per minute. That should stop him. Commercially, the Hall effect may prove useful in applications where a smooth (non-step function) sine wave at extremely low frequency is needed because, unlike conventional generators, the output voltage is independent of rate of rotation. This device can be used as a tachometer by mounting either the magnet or crystal on the shaft and reading the output frequency on an oscilloscope or other frequency meter. In the same manner, the home experimenter can make a simple anemometer.

### Analogue Computers

Continuing into the field of analogue computation, one finds the relation  $V_H = k I B_{max} \sin \theta$  (or  $\cos \theta$ ) to be potentially useful in several different applications. For



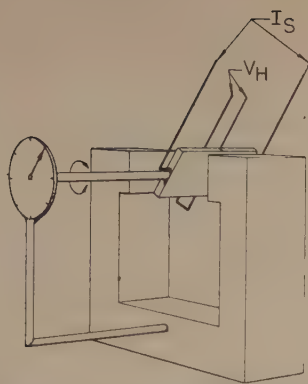


Fig. 6—Rotating Hall crystal.

example, in the solution of Fourier series one has many terms of the form  $a (\cos \theta \sin \phi + \sin \theta \cos \phi)$  or any other sin-cos combination. The rotation is calibrated in two scales  $90^\circ$  apart and proportional to  $\theta$  so that using one scale the output reads  $a \sin \theta$  and using the other,  $a \cos \theta$ . To solve,  $a \cos \theta \sin \phi$ , the crystal current is set to be proportional to  $a$  and the cosine rotation scale set to  $\theta$ . The output reads  $V_H = ka \cos \theta = b$ . The crystal current is then set to be proportional to  $b$  and the sine rotation scale set to  $\phi$ . The output now reads  $V_H = k^2 a \cos \theta \sin \phi$ . The procedure is repeated for a  $\sin \theta \cos \phi$ . A refinement of this unit is to put two crystals in series with the crystal current and rotating about the same current axis but with the voltage axes rotated by  $90^\circ$  so that with only one dial scale one crystal output reads  $\cos \theta$  and the other reads  $\sin \theta$  (Fig. 7). One can then read  $a \cos \theta$  and  $a \sin \theta$  simultaneously on two output meters.

This configuration can be used in an analogue computer unit known as a resolver, a device which transforms the variables  $r$  and  $\theta$  of the polar coordinate system into the variables  $x = r \cos \theta$  and  $y = r \sin \theta$  of the rectangular coordinate system. An interesting demonstration of this unit is to set a current magnitude (peak of rectified  $a-c$ ) and an angle on the resolver and to read the magnitude and angle on an oscilloscope by feeding the two output voltages to the  $x$  and  $y$  plates (Fig. 8). This device can also be used as a direction indicator. The two phased crystals are needed as each crystal shows mirror symmetry in its output if allowed to rotate more than  $180^\circ$ .

A further refinement of the rotating crystal multiplier is to cascade the crystals so that several multiplications are performed in one operation (Fig. 9). D-C amplifiers must be used to drive a succeeding crystal from the output of the previous one. With a large selection of crystals available, it is possible to choose a crystal of high output and proper impedance to directly drive the next crystal, which is chosen for low input requirements. If each crystal pair in a cascade is mounted with its own individual shaft and magnet,  $n$  dimensional multiplications of the form  $a \sin \alpha \cos \beta \cos \gamma \dots \sin n$  can be performed. Two or three stage units should be quite useful in some of the tedious calculations of this type made in x-ray crystallography.

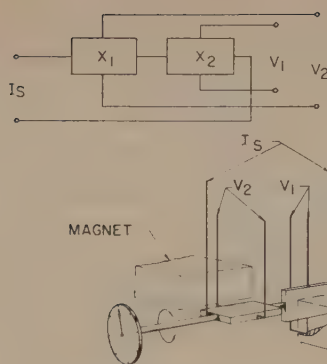


Fig. 7—Sine-cosine generator.

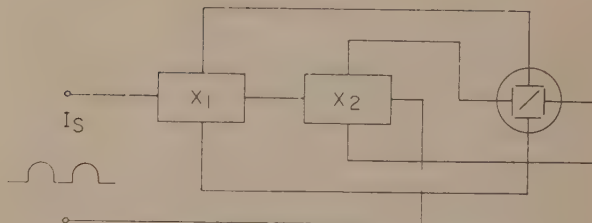


Fig. 8—Oscilloscope display of resolver.

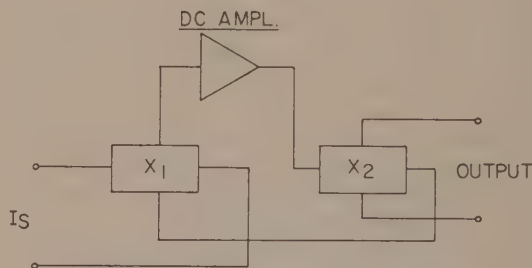


Fig. 9—Cascaded Hall crystals.

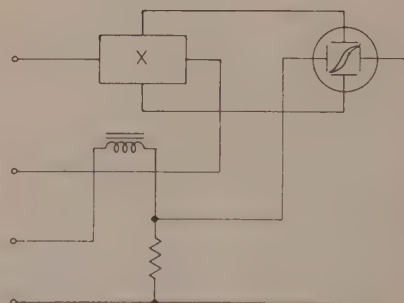


Fig. 10—Oscilloscope display of magnetic hysteresis curve.

### Applications With Electromagnet

If an electromagnet is substituted for the permanent magnet, the field  $B_{max}$  becomes a function of the magnetizing current, linear over some range for most magnetic materials. The hysteresis curve of the material of the core of the electromagnet may be displayed on an oscilloscope by putting the magnetizing current (proportional to  $H$ ) on the  $x$ -axis and the Hall voltage (proportional to  $B$ ) on the  $y$ -axis. (Fig. 10) This circuit can be



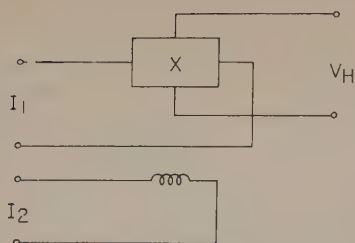


Fig. 11—Hall effect multiplier.

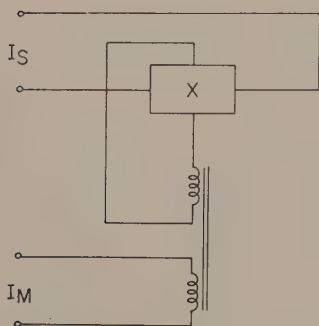


Fig. 12—The "ruckgekoppelte" Hall-generator.

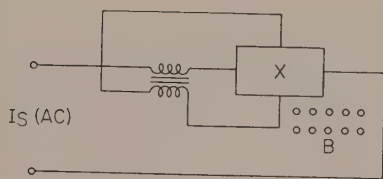


Fig. 13—Feedback to the current lead.

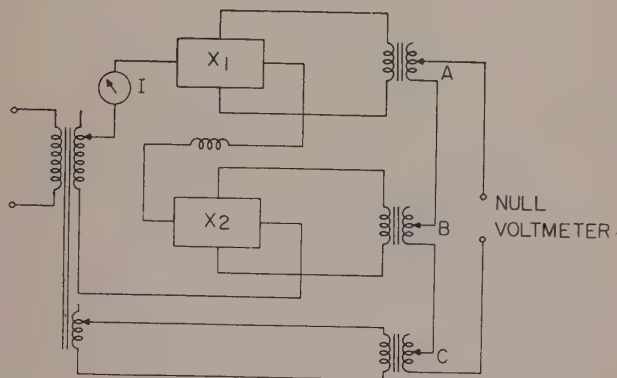


Fig. 14—Quadratic computer.

used in digital computation to register coincidence or overlap of events as there is no Hall voltage unless there is both a crystal current and a magnetizing current. By varying both crystal current and magnetizing current over a linear range, a simple analogue multiplier is made.<sup>(2)</sup> (Fig. 11). This can be used alone, so  $V_H = k I_1 I_2$  or it may be used to introduce another linear variable into the trigonometric multipliers previously described so that  $V_H = k I_1 I_2 \sin \theta$ .

## Feedback Effects

If the magnetic field obtained by loading the output with a coil is about the same as the driving field, very interesting effects can be obtained by feeding the output back into the input. In the back coupled Hall generator<sup>(4)</sup> (Fig. 12), a negative resistance device was made by driving the voltage output and a coil in series as the load of a vacuum tube. The amount of negative resistance is controlled by the driving current in the crystal. A variable pulse length generator circuit was made with pulse length controlled by the crystal driving currents. If *a-c* crystal current were used, feedback into the driving current circuit could be used in much the same manner as in the magnetic circuit (Fig. 13). Such feedback devices, especially in the negative resistance regions, may have wide circuit applications. Frequency response of these circuits, like all Hall effect circuits, is limited by the frequency limitations of associated circuit components as the Hall effect is frequency independent from *d-c* to far infrared.

## More Computer Applications

If the Hall crystal is driven by a constant *a-c* field and a variable *d-c* crystal current (or vice-versa) it becomes a modulator, giving an *a-c* output proportional to a *d-c* input. Modulators are widely used in analogue computers.

An interesting application of the *a-c* Hall effect is in a computer which finds the real roots or the real part of complex roots of the quadratic equation  $ax^2 + bx + c = 0$  (Fig. 14). This circuit is very similar to the quadratic analogue computer often shown to sophomore electrical engineers which uses a linear taper and a square taper potentiometer. The constants *a*, *b*, and *c* are set on their respective variable transformers. The crystal current is then varied to the value at which it reads zero for a real root, or reads a minimum for the real part of a complex root. Changing *b* from plus to minus (180° phase shift) has the same effect as reversing the sign of *x*, so the crystal current may vary from  $+x$  to  $-x$  in the range of the device. The device works as follows.  $V_a$  is proportional to *I*, *a*, and  $B_a$ . However,  $B_a$  is also proportional to *I* so  $V_a = k a I^2$ .  $V_b$  is proportional to *I*, *b*, and  $B_b$ . If this proportionality constant times  $B_b$  (also a constant) is made equal to *k*,  $V_b = k b I$ .  $V_c$  is set equal to *k c*. Thus,  $V_a + V_b + V_c = k (a I^2 + b I + c)$ . The value of *I* at which  $V_a + V_b + V_c = 0$  is a real root of the equation. If no null is read, but only a minimum value of the voltage sum, it is easily shown that this is the real part of a complex root. Set  $ax^2 + bx + c = m$ , a variable constant. Now let  $\frac{\delta m}{\delta x} = 0 = 2ax + b$ .  $x = \frac{-b}{2a}$ , the real part of  $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$  when *x* is complex.  $\frac{\delta^2 m}{\delta x^2}$  is positive, indicating that *x* is a minimum.

## Electrical Instrumentation

If the crystal and magnetic field are driven by different frequency currents, the Hall effect acts as a heterodyne generator or mixer (Fig. 15).  $V_H = k I_1 \sin \theta I_2 \sin$



$\phi = \frac{k I_1 I_2}{2} [\cos (\theta - \phi) - \cos (\theta + \phi)]$ . This device is useful well up into the microwave region.

A wattmeter can be made using the magnetic field arrangement as in the Hall effect ammeter and drawing the crystal current from between the lines concerned (Fig. 16). As the crystal is a pure resistance, the crystal current will be in phase with the line voltage,  $I_1 = k V_o \sin \omega t$ , while the magnetic field, derived directly from the line current, is in phase with the current,  $B = k' I_o \sin (\omega t + \phi)$ . So  $V_H = k'' V_o I_o \sin \omega t \sin (\omega t + \phi) = k'' V_o I_o \sin \omega t (\sin \omega t \cos \phi + \cos \omega t \sin \phi) = k'' V_o I_o (\sin^2 \omega t \cos \phi + \frac{\sin 2 \omega t}{2} \sin \phi)$ . The *d-c* component of this is  $\frac{1}{2\pi} \int_0^{2\pi} V_H d\omega t = k'' V_o I_o \frac{1}{2\pi} \int_0^{2\pi} (\sin^2 \omega t \cos \phi + \frac{\sin 2 \omega t}{2}) d\omega t = \frac{k'' V_o I_o}{2} \cos \phi = \frac{k''}{2} P$  in watts. In the microwave wattmeter (Fig. 17), the Hall effect measures  $E \times H = P$  directly. In the same manner a phase shift meter can be made for use with any two signals of the same frequency provided that correction is made for the inductance of the magnet winding.

It has been pointed out that when the Hall crystal and magnetic field are driven by two different frequencies, a heterodyne output is obtained, while if both are driven by the same frequency a signal of twice the driving frequency with a *d-c* component equal to the peak value of the signal is generated provided both driving currents are in phase. If they are out of phase by angle  $\phi$ , the *a-c* component of the output is distorted and the *d-c* component reduced by a factor of  $1/2 \cos \phi$ . This information has been applied by the Russians <sup>(7)</sup> to make a wave analyzer. Two magnets are driven by two signals of the same, but variable frequency and shifted in phase so that  $I_1 = I_o \sin \omega t$  and  $I_2 = I_o \cos \omega t$ . The crystals are driven in series by the wave to be analyzed, which may contain many frequencies at various phase relations. One *d-c* output will read  $V_1 = k I_o I_x \cos \phi$  and the other  $V_2 = k I_o I_x \sin \phi$ , so  $\phi$ , the phase angle of  $I_x$  with respect to  $I_o$  can be found as  $\phi = \tan^{-1} \frac{V_2}{V_1}$  and  $I_x$ , the  $\omega t$  component of the analyzed wave, determined.

### General Circuit Considerations

Certain aspects of Hall effect circuitry may be a little disconcerting to a man trained in vacuum tubes. There is no common ground between input and output. The output voltage is balanced with respect to a bias point which varies directly with the crystal input current. This causes considerable trouble in the use of *d-c* amplifiers, power supplies, and electronic millivoltmeters. Indium arsenide and indium antimonide make very low impedance devices, usually about one ohm. Germanium and silicon crystals range from a few ohms to a few thousand ohms depending upon the shape of the crystal and purity of the material. Hall effect devices are current rather than voltage operated. At high magnetic fields

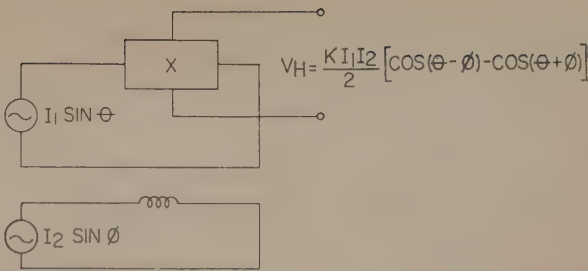


Fig. 15—Heterodyne generator or mixer.

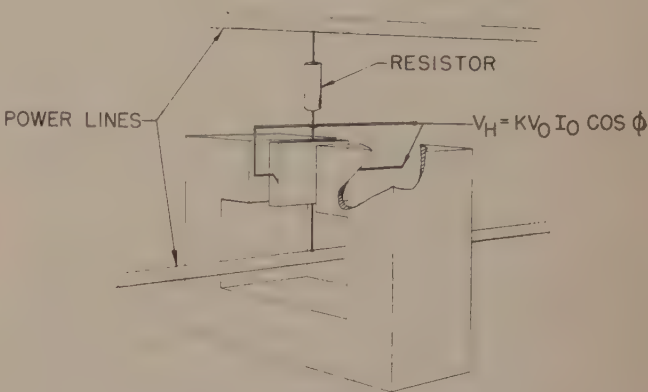


Fig. 16—Hall effect wattmeter.

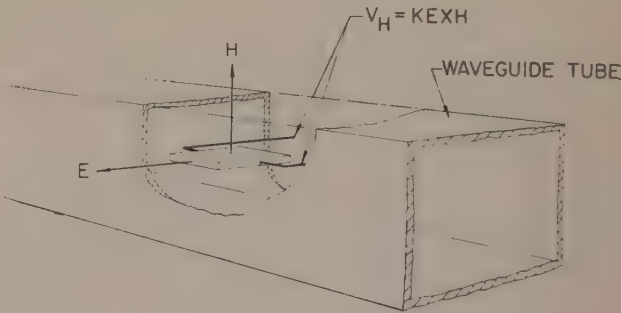


Fig. 17—Microwave wattmeter.

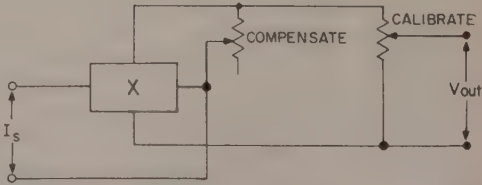


Fig. 18—Compensating and calibrating potentiometers.

the linearity of the output with field is a function of load impedance ranging from positive to negative curvature. For indium arsenide the linear load is about seven times the internal impedance of the crystal.<sup>(8)</sup> This factor may be different for other semiconductors. The maximum



usable current is determined by the heating of the crystal. As the temperature of the crystal increases, the resistivity and, as a result, the Hall coefficient varies, causing  $V_H$  to be non-linear with respect to  $I_S$ . Maximum current is that which causes maximum non-linearity tolerable in any particular application. In the case where the voltage electrodes are not properly placed, compensating potentiometers are used to make the zero field voltage equal zero (Fig. 18, 19). This condition is a necessity for many applications. A calibrating potentiometer is used to make the output fit some desired scale. These auxiliary circuits have little effect in the no load case but if not chosen carefully will destroy linearity of the device upon loading. In *a-c* applications care must be taken to avoid extraneous signal pickup by the leads.

### Three Terminal Hall Effects

Only the conventional Hall effect configuration has been discussed. There is also a three terminal configuration<sup>(6)</sup> (Fig. 20). Three leads are attached to a semiconductor crystal so they are at the vertices of a triangle. The current enters the crystal through one lead and leaves through the other two. (This is the simplest case. More than one input lead and more than two output leads can be used.) In a symmetrical case the currents in the two output leads will be equal. Application of a magnetic field perpendicular to the plane of current flow will cause a deflection of current carriers in a direction mutually perpendicular to the direction of current flow and the direction of the magnetic field and of a magnitude proportional to the strength of the magnetic field. Because of this deflection, more carriers will appear at one output lead than at the other. Depending upon the relation of the impedances in the output circuit to the crystal impedance either case 1 where  $R_3$  is large, and  $R_1$  and  $R_2$  are small compared to the crystal impedance, the current in one output lead will increase and the current in the other will decrease or case 2 where  $R_3$  is small, and  $R_1$  and  $R_2$  are

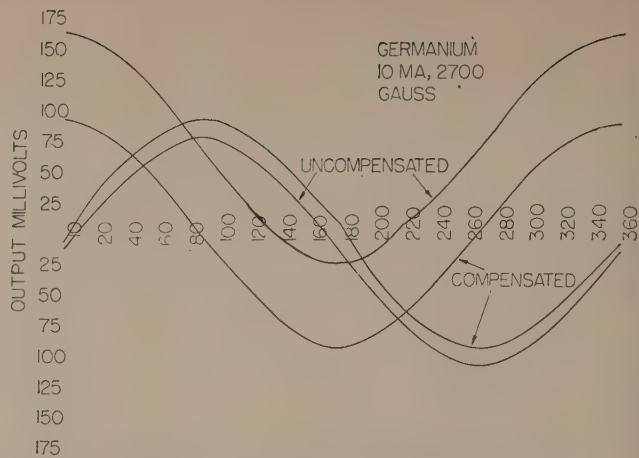


Fig. 19—Effect of compensating potentiometer.

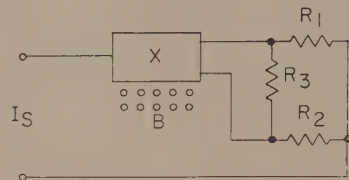


Fig. 20—Three terminal Hall effect.

large compared to the crystal impedance, a voltage comparable to the Hall voltage will be developed between the output leads. This can be applied almost anywhere the conventional Hall effect can and perhaps other applications can be found.

### Conclusion

The writer does not claim originality for most of these ideas. Many of them are quite old. If an application has been seen in two or more publications, no credit line was given. The writer wishes to thank Mr. M. T. Haddad of the Research Laboratories Division of the Bendix Aviation Corp. for assistance in literature survey.

It is hoped that a paper of this nature may stimulate some interest in Hall effect circuit experimenting.

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# Application of Transistors To Video Equipment

## Part 1

K. HIWATASHI\* Y. FUJIMURA\* K. SUZUKI\* N. MII\*

This is the first of a series of articles describing developments in the transistorization of television transmitting equipment in Japan. The portable camera-transmitter is described in this installment. Future articles will treat the sync-signal generator, and the image orthicon camera.

**T**RANSISTORIZED VIDEO EQUIPMENT, such as portable camera-transmitters, standard sync-generators and field-type image-orthicon cameras have been developed at the NHK Technical Research Laboratory. In fact, any television equipment can now be fully transistorized with the use of commercially available transistors, because of advances made in transistor and circuit techniques. High power horizontal deflection circuits and *uhf* circuits, however, still present difficulties under the present transistorization techniques.

### Portable Camera-Transmitter

The portable camera-transmitter (PCT) shown in *Fig. 1* is designed for field pickup. It contains approximately 120 transistors, a 1-inch vidicon (6326), a 3-inch picture tube (M-7136), a pencil tube (5876) and two high-voltage rectifiers (both 5642). It was developed from the pilot type which was manufactured in 1955 for experimental purposes and has been effectively used for televising several special events since April 1958.

### PCT Specifications

The features of this equipment are as follows:

Weight	18 kg.
Communicating distance	0.5 mi. (1.5 mi. with a directional antenna)
Operating time	3 hrs. or more
Radio frequencies used	2000 <i>mc</i> (video and sound) and 153 <i>mc</i> (external sync-signal and intercommunication)
Optical system	Two 16-mm turret type lenses
Overall signal to noise ratio	33 <i>db</i> .
Resolution	400 lines

The camera contains a preamplifier, a deflection

circuit, a blanking amplifier and a view-finder, and is shown in block diagram form in *Fig. 2*.

### Preamplifier

The preamplifier contains 13 drift transistors and has a current gain of 80 *db*. The schematic diagram of aperture correction in the amplifiers is shown in *Fig. 3*.

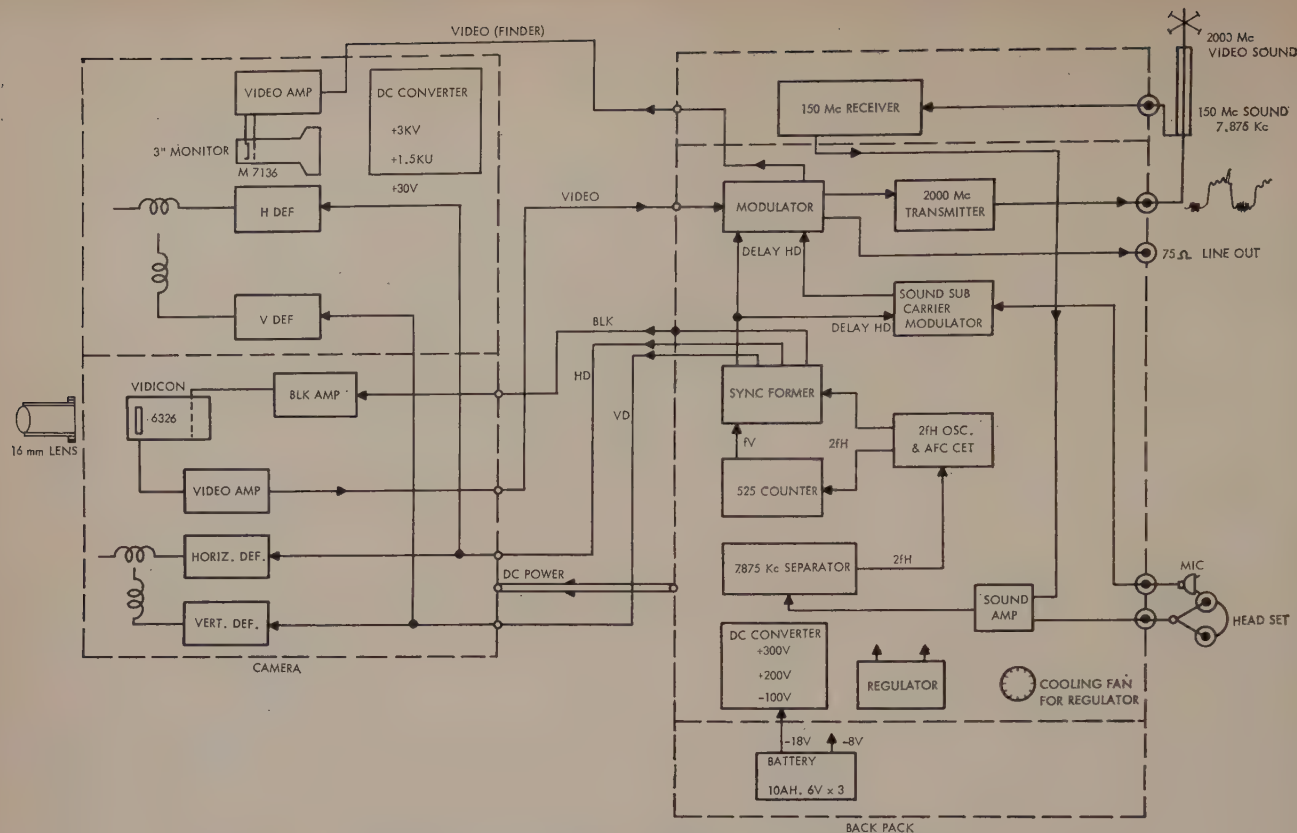
With the variable capacity of the emitter properly adjusted, the phase compensator (T5) minimizes the phase distortion of the high-peaked circuits consisting of T6-T7 and T8-T9.



**Fig. 1—Transistorized portable camera-transmitter.**

\*Television Research Section, NHK Technical Research Laboratory, Tokyo, Japan.





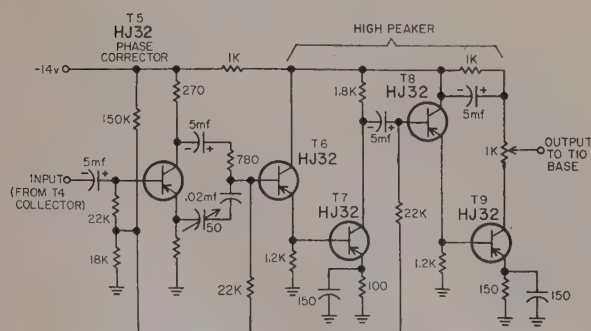
**Fig. 2—Block-diagram of portable camera-transmitter.**

With these circuits, the overall frequency characteristic shows a possibility of about 9-db aperture correction on 3-4 mc.

The output video signal of the preamplifier, approximately 5 *ma* peak to peak, is fed to the modulator through the camera cable, and is inserted into the intercommunication subcarrier after being clamped with delayed *HD*. The signal output of the modulator then modulates the grid of the 2000-*mc* transmitting tube (5876) with 0.5- to 1-volt signal.

## Sound Modulator

The schematic diagram of the sound modulator is shown in *Fig. 4*.  $T_5$  is a 2.7-mc crystal oscillator, and this carrier is amplitude modulated with the audio



**Fig. 3—Schematic diagram of aperture correction.**

signal of the output of *T1*. The modulated 2.7-mc signal is gated by the delayed HD pulse, which is fed into the base terminal of *T3*.

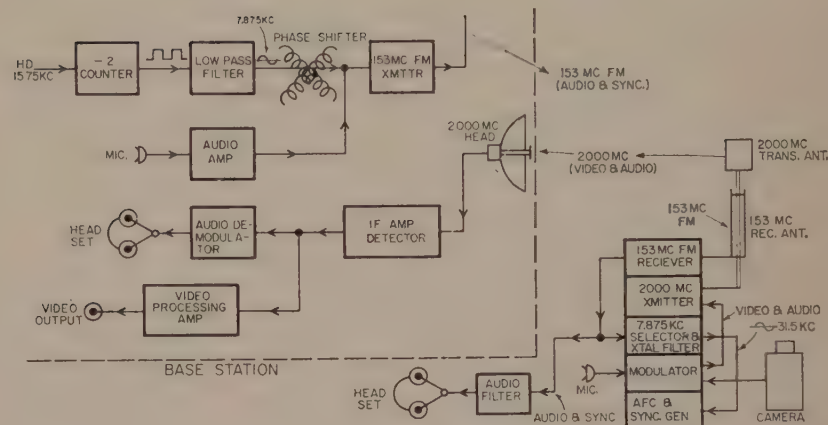
The output of the 2.7-mc L-C filter, which has the waveform shown in Fig. 4, is inserted into the blanking period of the video signal. The cameraman can talk freely with the base station using two ways of the time-divided multiplex channels—the 2000-mc channel and the fm channel (153 mc).

The 2000-*mc* transmitter of this PCT is frequency modulated and uses a circular polarized waveform for protection from the multipath interference of microwaves. The frequency modulation is achieved by modulating the grid of the transmitter tube. In this case the *fm* deviation is about 2 *mc* against the video input of 0.5 volts.

The sync-lock is due to the synchronized external signal from the base station. Because of the adoption of this system, the random disturbance encountered in a microwave transmission does not interfere with the sync signal of the other camera chain at the base station and it permits the mixing of the video signal of the PCT in other camera outputs at the base station.

The external sync-signal, which is a 7.875 *kc* sine wave corresponding to  $\frac{1}{2}$  the horizontal frequency, comes from the *fm* transmitter of the base station with a multiplexed sound signal on 153 *mc, vhf*. This sync and sound signal drives the frequency separator circuit. The frequency separator circuit shown in



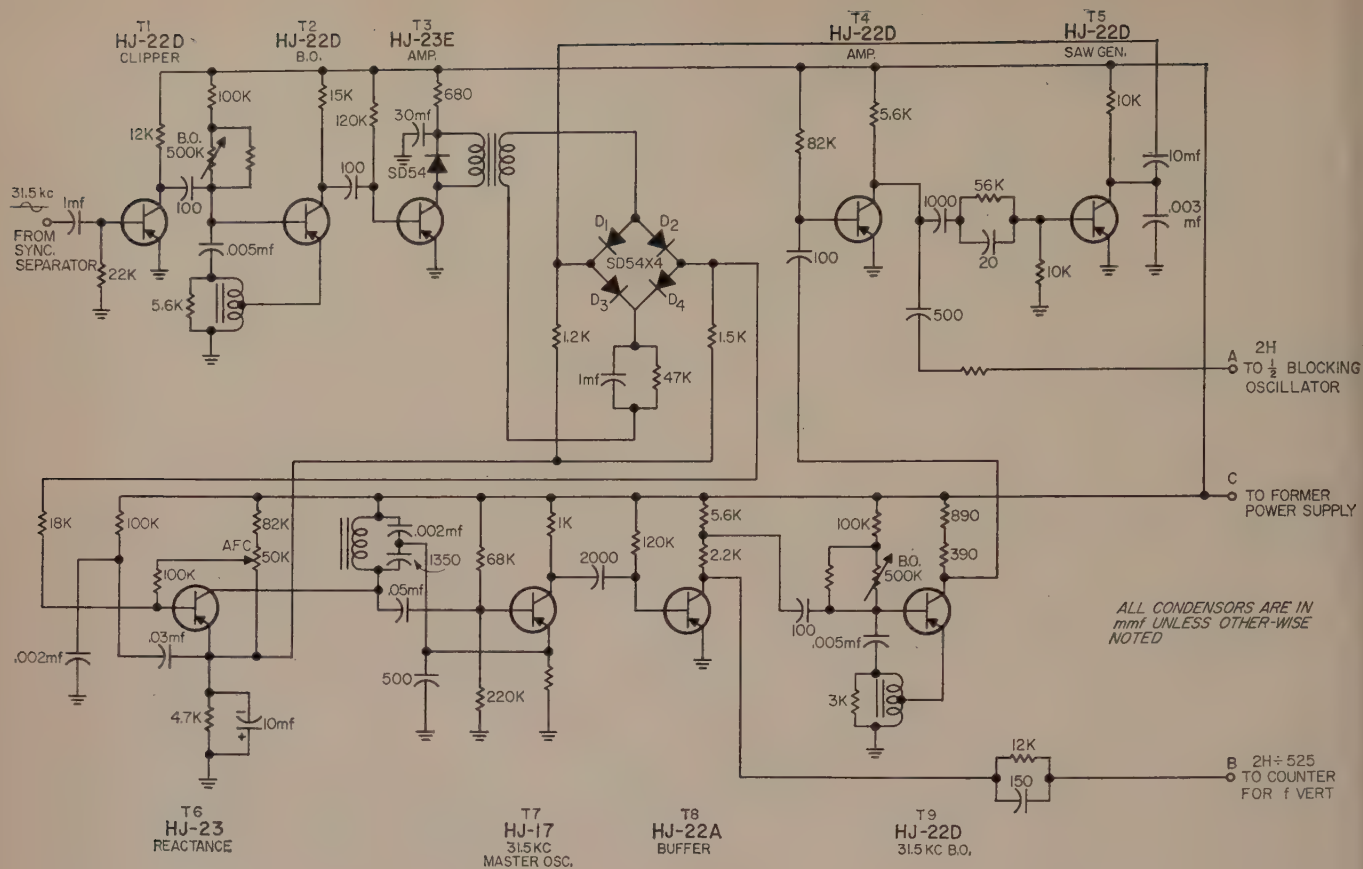
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**Fig. 6—Schematic diagram of 7.875 kc ( $f_h/2$ ) separator.**

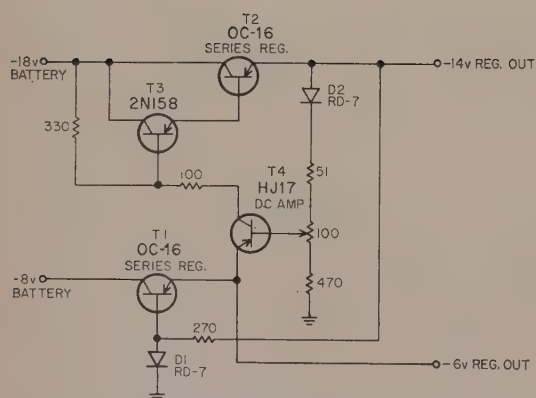
Due to transistorization, the size of the frequency separator has been reduced to as small as 70 x 25 mm. The 7.875 kc sine wave sync signal multiplies its frequency four times and drives the *afc* circuit through the 31.5 kc crystal filter. The schematic diagram of the *afc* circuit is shown in Fig. 7. The operation of this circuit is analogous to that of the corresponding electron tube circuit.

Series type regulators are used for the power source. One is shown in Fig. 8, in which  $T1$  is a series





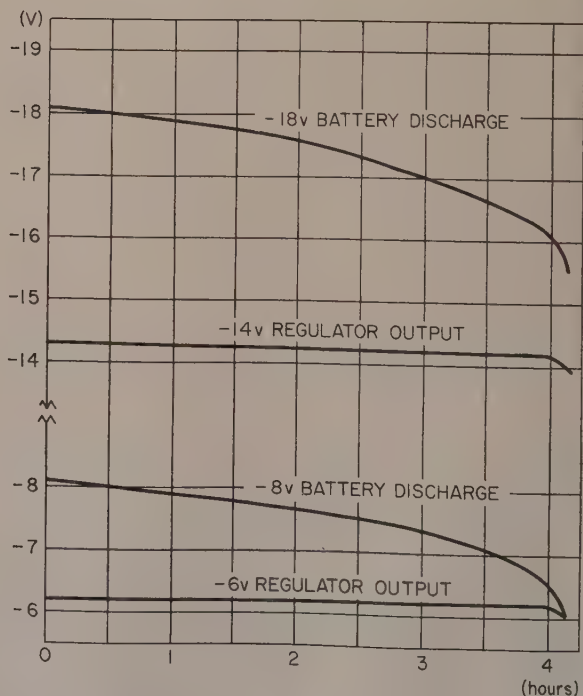
**Fig. 7—Schematic diagram of *a/c* circuit.**



**Fig. 8—Schematic diagram of series regulator.**

### TABLE I—Interchangeability Chart

Japanese Transistor	Class of Service	Replace by EIA Type
HJ17	Audio Amp	2N34, 2N37, 2N217
HJ22D	IF Amp	2N78, 2N135, 2N218
HJ23E	Converter	2N219, 2N172, 2N252
HJ32	HF Amp	2N247, 2N274, 2N370
HJ55	Switching	2N219, 2N172, 2N252
2N158	Audio power	2N158
2N301	Audio power	2N301
2T51	HF Amp	(NPN)—HJ22D
2T71/HJ30	HF Amp	(NPN)—HJ23E
OC16	Audio power	



**Fig. 9—Battery discharge and regulation curves.**



regulator for  $-6v$ ;  $T2$  and  $T3$  are for  $-14v$ ;  $T4$  is a feedback amplifier; and  $D1$  and  $D2$  are silicon reference diodes.

The overall discharge curve of the PCT in Fig. 9 shows that the voltage drop becomes less than on the order of  $10^{-3}$ .

The variations of the filament voltage and of the electrode voltage of a 1-inch vidicon and that of the pencil tube are so small and the stability during operation is so high that once the equipment is set, the cameraman simply has to control the optical focus and the lens iris.

The power consumption of PCT is 36 watts. The base station contains a camera control unit (CCU), which is the same as the usual image-orthicon CCU in size, and a 2000 mc microwave receiving head including a 150 mc fm transmitter and antennas. (See Fig. 10.)

The camera control unit of PCT is usually set and  
(To be continued)

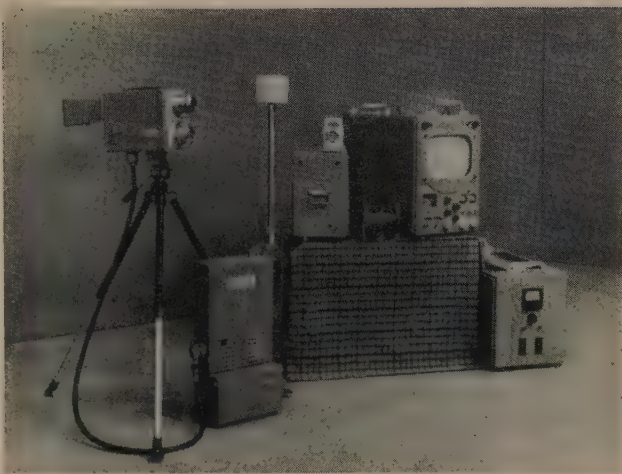


Fig. 10—Portable camera-transmitter and base station equipment.

operated with other image-orthicon cameras in the vehicle designed for remote pickup.

# Applications Engineering Digests

## APPLICATIONS ENGINEERING DIGEST NO. 36

**Thermistors and Varistors;** Victory Engineering Corp., Union, New Jersey.

### Background of Thermistors

The basic characteristics of semi-conductors were discovered and investigated over one-hundred years ago. As early as 1834, Michael Faraday noted and recorded the high "negative temperature coefficient of resistance" of certain semi-conductors. His discovery was nothing more than a curiosity at that time.

Work with temperature sensitive elements progressed very slowly for many years due to the difficulty of producing units with high stability. It was only in recent years, after extensive research and development work had been undertaken, that a satisfactory product was produced. World War II uses provided industry with its first sizable production volume and only since that time has the introduction of many and varied commercial applications of these new and versatile units been possible.

### Some Typical Uses of Thermistors

#### Temperature Measurement

Since the resistance of a thermistor is an exact and reproducible function of the temperature, it makes it an ideal device for temperature measurement purposes. The large change in resistance with temperature change enables the associ-

ated use of relatively simple indicating equipment where precision measurement is not required.

Figure 36.1 shows how automobile manufacturers use a simple series connection of a thermistor and a heated bi-metal indicator gauge to replace the older liquid-operated engine temperature device.

High precision measurements can be made with a bridge type circuit as shown in Fig. 36.2. High resistance thermistors may be used so that the bridge leads do not affect the readings. This is an advantage over thermocouples which require special compensating leads and cold junction compensation. Two thermistors may be used in adjacent arms of a bridge to indicate temperature differentials as in very accurate calorimetric work.

### Temperature Control

The use of thermistors to control temperature is very closely related to their use in measurement of temperature. In industrial and scientific work, temperature control to  $0.001^\circ$  has been achieved with the aid of thermistors as shown in Fig. 36.3. The ease with which the operating point may be adjusted in a thermistor bridge is one of the outstanding features. Such a bridge is suitable to provide a signal for extremely precise servo-type control systems.

Thermistors have found extensive use in aircraft cabin temperature and de-icing controls, domestic heating sys-

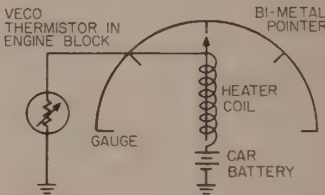


Fig. 36.1—Automobile temperature gauge.

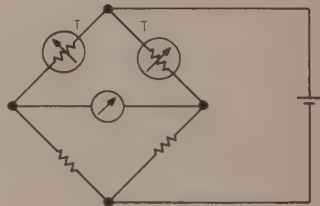


Fig. 36.2—Bridge-type measurement.

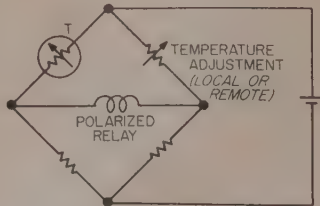


Fig. 36.3—Thermistor control circuit.



tems, refrigeration, food processing, etc. A bridge circuit using two thermistors may be used to control the indoor temperature and at the same time anticipate the amount of heat required by observing the outdoor temperature—thus preventing excessive lags in the heat supply due to changing outdoor temperature.

### Transmission Circuit Elements

One of the most important uses of thermistors is in the transmission equipment field. They are used for such purposes as volume limiters, voltage regulators, compressors and expanders, automatic gain regulators, overload protectors, and oscillator amplitude stabilizers.

In the case of voltage regulators and volume limiters, thermistors may be

used to stabilize output voltage in circuits where there is a considerable range of input voltages. If a suitably chosen value of resistance is placed in series with a thermistor, the voltage across the combination can be maintained almost completely independent of the current over a wide region of values. This principle finds useful application in the voltage regulation of alternating or direct current power supplies where thermistors provide regulation with negligible distortion. A simple circuit, shown in Fig. 36.4, illustrates this basic principle.

In volume limiter devices, the same principle is used to provide a constant or limiting value of output voltages over a specific working range thus enabling thermistor volume regulators to accommodate large volume changes without producing wave form distortion.

(Circle 198 on Reader Service Card)

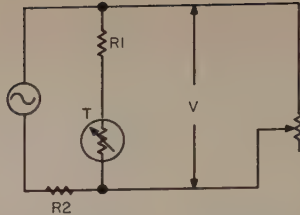


Fig. 36.4—Thermistor regulating circuit.

tion. Audio frequency speech circuits so designed have important advantages over other devices in use. Other uses are for compressors and expanders, automatic gain regulators, overload protection and oscillator amplitude stabilizers.

## APPLICATIONS ENGINEERING DIGEST NO. 37

### Fast Pulse Response Measurements Using an Oscilloscope; Lansdale Tube Co., Lansdale, Pa.

#### Purpose

The purpose of this project was to construct a graph of apparent vs. actual rise time of commonly used high speed oscilloscopes in order to simplify fast pulse response measurements.

#### Theory

The equation governing the rise time that is read on an oscilloscope is given by:

$$X^2 = a^2 + b^2 \tag{1}$$

where  $X$  is the apparent rise time that is read on the oscilloscope,  
 $a$  is the rise time combination of the oscilloscope and the plug-in amplifier.

$b$  is the actual rise time of the pulse being measured.

Solving for " $b$ " gives the expression:

$$b = \sqrt{X^2 - a^2} \tag{2}$$

#### Procedure

As an example, assume that an apparent rise time of 25 millimicroseconds is read on a Tektronix type 541 oscilloscope, using a plug-in preamplifier type

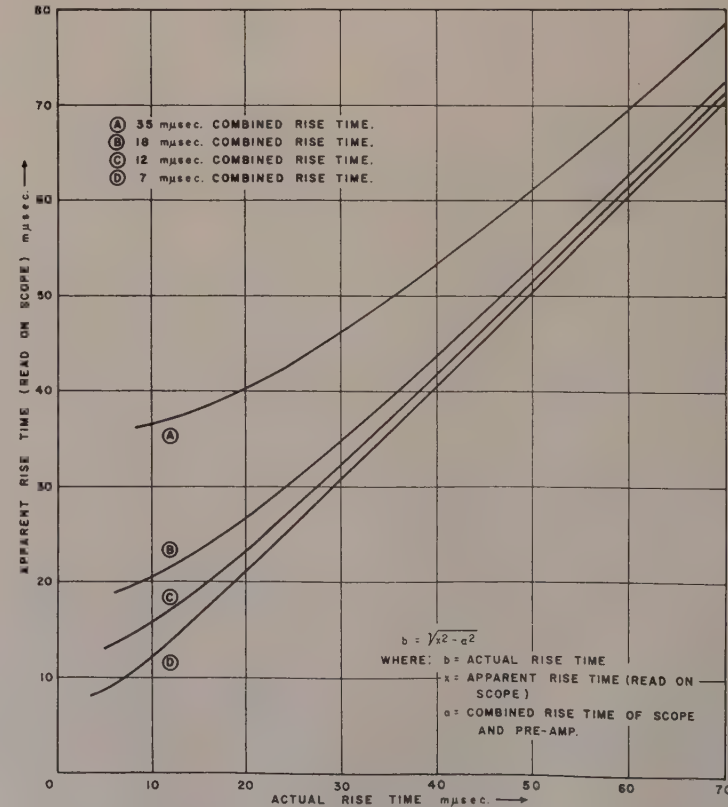


Fig. 37.1—Actual rise time vs. Apparent rise time as read on oscilloscope.



53/54C. The actual rise time can be calculated as follows:

a, from the manufacturer's specifications is given as 15 millimicroseconds,  
Using Equation (2):

$$b = \sqrt{X^2 - a^2}$$

Substitute the known values:

$$b = \sqrt{625 - 225}$$
$$b = \sqrt{400}$$
$$b = 20 \text{ millimicroseconds}$$

It can now be seen that the actual rise time of the pulse being measured is 5 millimicroseconds faster than the apparent rise time.

The rise time specifications of some commonly used oscilloscopes and pre-

amplifiers combinations are given in Table I.

(Circle 199 on Reader Service Card)

TABLE I

Oscilloscope	Plug-In Preamplifiers		
	53/54A	53/54C	53/54K
Type 541,545	0.018 $\mu$ sec	0.015 $\mu$ sec	0.012 $\mu$ sec
Type 531, 535 536	0.035 $\mu$ sec	0.035 $\mu$ sec	0.031 $\mu$ sec

APPLICATIONS ENGINEERING DIGEST NO. 38

*The Use of Silicon Junction Diodes for the Protection of A-C and D-C Meter Circuits;* Pacific Semiconductors Inc., Culver City, Calif. (P. G. Ducker)

Overload Protection

It is an established fact that sensitive low range a-c and d-c instruments can be easily damaged when their meter movements are subjected to overloads, on the order of three to four times the rated full scale deflection. This problem has been solved in the past partly by the application of thermal, or similar devices, which inherently require a trip and/or reset time.

It has been found that silicon diodes lend themselves ideally to this problem of overload protection. Being passive devices, they have an instantaneous action and do not have a reset time. As will be described in the following sections, either the non-linear characteristics of a forward biased diode, or the Zener region of a reverse biased diode may be used.

**Protection of D-C Microammeters**

Most microammeters with a full scale deflection of 50  $\mu$ a, have an internal resistance of 2000 ohms. This represents a full scale deflection of 0.1 volts. Since we want the diode to conduct as soon as possible to carry the excess current, a resistance  $R_s$  is used in series with the meter to increase the terminal voltage to almost that of the conduction voltage of the diode. This circuit is shown in Fig. 38.1 illustrating a Model 27 Simpson microammeter with a full scale deflection of 50  $\mu$ a and internal resistance  $R_M$  of 200 ohms. The value of  $R_s$  is found from the following equation:

$$R_s = \frac{E_f}{I_M} - R_M$$

where  $I_M$  = Full scale deflection of the microammeter, in amps.  
 $R_M$  = Internal resistance of meter, in ohms.  
 $E_f$  = Point of beginning conduction of diode, typically 0.3 volts.

Then for our example,

$$R_s = \frac{0.3}{50 \times 10^{-6}} - 2000 = 4000 \text{ ohms}$$

Protection of D-C Voltmeters  
Use of Diode Forward Characteristics

The 50 microampere meter discussed in the previous section can be adapted to a 20,000 ohm/volt voltmeter by the addition of suitable voltage multiplier resistors. The circuit is illustrated in Fig. 38.2.

Use of Zener Diodes to Expand the Scale of D-C Microammeters and Low-Range Milliammeters

It is sometimes necessary to obtain measurements of voltage over a limited range. Zero suppressed instruments are used for this application. This means that all voltages below a certain value applied to the meter will not cause any movement of the pointer. The meter is calibrated so that the lowest voltage value takes the place of the conventional zero.

The Zener diode can be utilized for zero suppression as shown in Fig. 38.3. The Zener diode voltage determines the threshold voltage of the meter, and the

voltage multiplier resistance determines the full scale deflection. Since the voltage scale is non-linear, it is necessary to calibrate the meter scale against some known standard.

(Circle 200 on Reader Service Card)

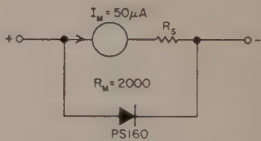


Fig. 38.1—D-C microammeter protection.

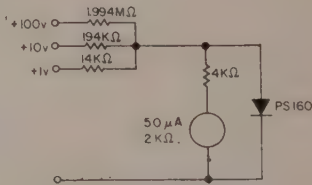


Fig. 38.2—D-C voltmeter protection.

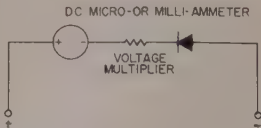


Fig. 38.3—Zener diode for scale expansion.



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Some Design Consideration for High-Frequency Transistor Amplifiers	Bell Syst Tech JI November 1959	Problems of interaction between output and input of amplifier is illustrated and the two common design approaches to a solution of the problem is discussed.	D. E. Thomas
The Measurement of Semiconductor Diode Switching Characteristics	Br Comm & Elecncs November 1959	Test equipment which evaluates the diode in terms of its effective resistance at a preselected time after switching is described.	J. N. Barry S. F. Fisher
A New Transistorized Negative-Impedance Telephone Repeater	Comm & Elecncs (AIEE) November 1959	Theory of operation, description, performance, application, and installation of a series-shunt unit with a variable gain control.	R. P. Dimmer E. L. Roback
All Transistor Magnetic-Core Memories	Comm & Elecncs (AIEE) November 1959	Properties of special small ferrite cores which were developed for use in high-speed transistor-drive memories are discussed.	B. T. Goda W. R. Johnston S. Markowitz M. Rosenberg R. Stuart-Williams
Transistor-Magnetic Control Circuit for Aircraft Electric Systems	Comm & Elecncs (AIEE) November 1959	Combination of semiconductor diodes and transistors with square-loop magnetic cores for maximum use of their desirable characteristics.	A. W. Pratt
An Electric Analog of Heat Flow in Power Transistors	Comm & Elecncs (AIEE) November 1959	The electric analog was constructed to facilitate a study of instantaneous crystal temperatures under various pulsed conditions.	J. Reese W. W. Granne- mann J. R. Durant
Analysis and Design of a Transistor Linear-Delay Circuit	Comm & Elecncs (AIEE) November 1959	Some important fundamental limitations on the operation and design of the circuit are presented. Experimental data are included.	R. P. Nanavati
Analysis of Magnetic Amplifiers with Diodes	Comm & Elecncs (AIEE) November 1959	Analysis and interconnection of basic magnetic amplifiers. Analysis of doubler circuit.	P. R. Johannessen
Power Switching with Junction Transistors	Control Engineering November 1959	Relationships are presented for preliminary design planning in large-signal or pulse applications for control circuitry.	A. N. DeSautels
Determination of Safe Power Level in Transistor Circuits	Elecl Design News November 1959	Method for determining whether or not a transistor is being operated with safe power levels is described.	A. Olivier
Determination of the Bandwidth of Multistage Transistor Amplifiers	Elecl Design News November 1959	Method is presented for finding the overall bandwidth of two- and three-stage transistor amplifiers.	P. G. Thomas
An Elementary Design Discussion of Thermoelectric Generation	Elecl Engineering October 1959	Composite view of thermoelectric generation. Thermocouple fundamentals. Thermopile configurations. Designing with semiconductor materials.	E. W. Bollmeier
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Self Oscillating Frequency Changers	Elecl App (Philips) Vol 19 No 4	Theoretical discussions of the oscillatory condition, phase correction, amplitude control and conversion gain.	B. G. Dammers A. G. W. Uitjens R. A. Polzl
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Compound Semiconductors	Electronic Engg (Br) November 1959	Discussion of important semiconductor parameters; considerations to compound semiconductors; values of mean parameters are given.	D. A. Wright
A Transistorized L.T. Regulator	Electronic Engg (Br) November 1959	A simple circuit using a transistor and two zener diodes is given and its design and performance described.	J. H. Deichen
Thermoelectric Cooling	Electronic Engg (Br) November 1959	Historical background, semiconductor thermocouples, and practical applications discussed.	Comm from G.E. Res. Lab. Wembly, Eng.
A Delta Modulation System Using Junction Transistors	Electronic Engg (Br) November 1959	A delta modulation system operating at a digit frequency of 14 kc is described which provides a simplex speech link with good intelligibility.	B. E. Williams
Electroluminescent Cell Application	Elecl Rad Eng November 1959	The efficiency of some types of EL cell (i.e., the ratio of power transformers into visible light to the electrical input power) was measured at various frequencies; applications discussed.	R. B. Lochinger M. J. O. Strutt
Transistorized Remote Control Receiver	Elecl Equip Engg November 1959	Designed for 27 mc range, 4-transistor superregenerative receiver operates relay from audio tone modulation of transmitted carrier.	D. B. Hall
Use Power Zener Diodes for Protection	Elecl Equip Engg November 1959	Three circuit for employing diodes for surge protection of transistors in d-c to d-c converter.	R. E. Learned
The Tunnel Diode—Its Action and Properties	Electronics November 6, 1959	Negative conductance property is explained using energy-band diagrams. Breakdown characteristics are compared with ordinary diodes.	B. Sklar
Transistorized Receiver for Marker Beacon Use	Electronics November 13, 1959	Circuit description of a super-heterodyne receiver which provides both aural signals and airline-type colored lights.	F. Smith



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Transistors in Switching Circuits	Industrial Labs November 1959	Transistors closely approach the ideal switch, zero impedance when it is ON, infinite impedance when it is OFF.	A. J. Leitch E. E. Rabin
Characteristics of Degenerative Amplifiers Having a Base Emitter Shunt Impedance	IRE Trans Audio Nov Dec 1959	An analysis is performed on the effect of the impedance used between base and emitter on the input impedance of the stage.	W. D. Roehr
Diffusion of Oxygen in Silicon	Jl Appd Physics November 1959	The diffusivity and solubility of oxygen in silicon has been measured by oxygen diffused in the silicon.	R. A. Logan A. J. Peters
Infrared Studies of Birefringence in Silicon	Jl Appd Physics November 1959	Permanent and elastic strains in silicon crystals grown by the Czochralski technique have been studied by observing the crystal birefringence.	S. R. Lederhandler
Surface-Dependent Losses In Variable Reactance Diodes	Jl Appd Physics November 1959	Diode series equivalent resistance component in excess of the calculated integrated bulk resistance varies with frequency and atmosphere.	D. E. Sawyer
Temperature Dependence and Lifetime in Semiconductor Junctions	Jl Appd Physics November 1959	These can be held to a minimum by using material with a minority carrier lifetime below a certain maximum value.	D. A. Jenny J. J. Wysocki
Some Effects of Low Fields on Luminescence of CdS	Jl Appd Physics November 1959	The effect produced on luminescence and conductivity in pure CdS crystals by application of electric fields up to 1000 V/cm are reported.	C. E. Bleil D. D. Snyder
Temperature Dependence of Fractional Velocity Changes in a Germanium Single Crystal	Jl Appd Physics November 1959	An ultrasonic interferometer technique is used for measuring the temperature dependence of relative changes in elastic constant has been utilized to study the variation of Cu for germanium.	F. Stein N. G. Einspruch R. Truell
Light Emission and Noise Studies of Individual Microphones in Silicon P-N Junctions	Jl Appd Physics November 1959	At low currents in the prebreakdown region only a few light emitting microplasmas are present.	A. G. Chynoweth K. G. McKay
Two-Terminal Assymetrical and Symmetrical Silicon Negative Resistance Switches	Jl Appd Physics November 1959	By making use of an emitter region shorted by a metallic contact to an adjacent base region a new form of $p-n-p-n$ switch is obtained.	R. W. Aldrich N. Holonyak, Jr.
Electrical Conductivity of Single Crystals of MgO	Jl Cheml Physics November 1959	The electrical conductivity of magnesium oxide at temperatures in the region of 1300°C is observed to depend on the partial pressure of oxygen surrounding the sample.	S. P. Mitoff
Optical Properties of Tin and Lead Activated Calcium Metasilicate Phosphors	Jl Electrochem Soc November 1959	The preparation and optical properties of two new tin-activated calcium metasilicate phosphors are described.	R. W. Mooney
Cadmium Sulfide Photoconductive Sintered Layers	Jl Electrochem Soc November 1959	Parameters may be predicted and controlled to give a resultant reproducible layer of desired electrical and optical characteristics.	M. J. B. Thomas E. J. Zdanuk
The Action of Nickel and Cobalt in Electroluminescent Zinc Sulfide Phosphors	Jl Electrochem Soc November 1959	The similarities and differences of nickel and cobalt in both blue and green emitting phosphors are discussed.	P. Goldberg
The Temperature Dependence of the Low Level Lifetime and Conductivity Mobility of Carriers in Silicon	Jl Elecncs & Cont (Br) August 1959	Temperature dependence has been found to be consistent with that expected from the theory based on a low level of injection, a low density of recombination centers, and a single energy level for the recombination centers.	D. M. Evans
A Modification of the Theory of Variation of Junction Transistor Current Gain with Operating Point and Frequency	Jl Elecncs & Cont (Br) August 1959	A modification solution is discussed of the continuity equation for minority current flow in junction transistors.	A. W. Matz
Electrical Properties of Alkali Antimonides	Jl Phys Soc Japan November 1959	These antimonides can be classified into a group which transmits from $p$ -to- $n$ -type with successive activation, and a group which remains constantly $p$ -type.	S. Imamura
Photoelectric Properties of Alkali Antimonides	Jl Phys Soc Japan November 1959	Photoemission, photoconduction, and optical absorption of sodium, potassium, rubidium, and cesium antimonides were studied at several stages in the course of preparation.	S. Imamura
Effect of External Illumination on Carrier Lifetime in Semiconductors	Jl Phys Soc Japan November 1959	The lifetime of excess carriers in a nondegenerate semiconductor which is illuminated with light in the fundamental absorption band and a longer wavelength is discussed.	J. Okada
Electron Mobility of Indium Arsenide Phosphide [In(As <sub>7</sub> P <sub>1-7</sub> )]	Jl Phys Chem Solids Volume 12 No 1	Electron mobility is calculated using existing evidence for the band structure of these materials.	H. Ehrenreich
Properties of Oxygen in Germanium	Jl Phys Chem Solids Volume 12 No 1	On heat treatment donors are introduced in the crystal; at a higher temperature the donors disappear.	J. Bloem C. Haas P. Penning
Hot Electron in $n$ -Type Germanium	Jl Phys Chem Solids Volume 12 No 1	The non-ohmic current in a many-valley semiconductor has been investigated by considering scattering by acoustical and optical modes of vibrations and intervalley scatterings.	J. Yamashita K. Inoue
Phase Equilibria and Semiconducting Properties of Cadmium Telluride	Philips Res Repts August 1959	The relation is studied between the electrical and optical properties of single crystals of cadmium telluride.	D. deNobel
Surface Recombination of Silicon	Philips Res Repts August 1959	The surface recombination velocity of electrons and holes in silicon is investigated by measuring the photovoltaic effect of a $p-n$ junction alloyed on a thin silicon wafer.	H. U. Harten
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The Use of Thermistors in the Ebullioscopic Determination of Molecular Weights	Philips Tech Rev November 1959	Brief description of an apparatus; boiling point being measured with a thermistor resistance thermometer.	J. G. vanPelt
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Exciton Spectrum of Cadmium Sulfide	Physical Review November 1 1959	The reflectance and fluorescent spectra of hexagonal CdS crystals have been measured at 77° and 4.2° K using polarized light in the region of 5000Å.	D. G. Thomas J. J. Hopfield
Optical Absorption in Pure Single Crystal InSb at 298° and 78° K	Physical Review November 1 1959	The absorption spectral of single crystal homogeneous InSb were measured in the spectral range 5 to 10 microns at temperatures of 78° K and 298° K.	S. W. Kurnick J. M. Powell
A-C Impedance Measurements on Insulated CdS Crystals	Physical Review November 1 1959	Induced conductivity measurement were made on crystals insulated with mylar and with no charge injection introduced at the electrodes.	H. Kallman B. Kramer G. M. Spruch
Photoconductive and Photoelectromagnetic Lifetime Determination in Presence of Trapping. I. Small Signals	Physical Review November 15 1959	The photoconductive and photoelectro-magnetic effects of impurities in semi-conductors are considered.	A. Amith
Nature of Defects Arising from Fast Neutron Irradiation of Silicon Single Crystals	Physical Review November 15 1959	A method is described for determining the range of sizes which damaged regions (created by fast neutrons) may have in a silicon single crystal.	R. Truell
Crystal Potential and Energy Bands of Semiconductors I Self-Consistent Calculations for Diamond	Physical Review November 15 1959	Calculation of experimental features of the energy bands of diamond and zinc-blend-type semiconductors.	L. Kleinman J. C. Phillips
Electron Emission from Si p-n Junction	Physical Review November 15 1959	A junction with a 1-cm diameter and a reverse bias of 0.1 amp gives rise to an emission current around its perimeter of the order of $10^{-13}$ amp.	B. Senitzky
Correlation Effects in Impurity Diffusion	Physical Review November 15 1959	Expressions are developed giving the correlation factor for an impurity diffusing in an otherwise pure lattice.	J. R. Manning
Electroluminescence at Low Voltages	Physical Review November 15 1959	Electroluminescence occurs in activated ZnS then films at 1.5 volt rms corresponding to electron energies less than the band gap and mean energy of the photons emitted.	W. A. Thornton
Comments on Microelectrodes	Proceedings IRE November 1959	Metal and fluid-filled electrodes are discussed. Includes transistorized head-stage.	R. C. Gesteland B. Howland J. Y. Lettvin W. H. Pitts
Semiconductor Varactors using Surface Space-Charge Layers	Proceedings IRE November 1959	A family of semiconductor devices characterized by a voltage-sensitive capacitance that resides in the space charged region at the surface of a semiconductor bounded by an insulating layer is proposed.	W. G. Pfann C. G. B. Garrett
The Magnetic Susceptibility of Bismuth Telluride	Proc Phys Soc (Br) November 1959	Measurements of the susceptibility of Bi <sub>2</sub> Te <sub>3</sub> over the temperature range 100°K to 600°K with magnetic field are reported.	R. Mansfield
Grinder for Sectioning Solid Diffusion Specimens	Rev Scientific Inst November 1959	Useful for specimens in which the average diffusion distance is a very few microns. Descriptive of instruments and evaluations.	H. W. Schamp D. A. Oakes N. M. Reed
Three - Dimensional Scintillation Dosimeter	Rev Scientific Inst November 1959	A dosimeter for electron beams has been constructed which utilizes the luminescence of plastic phosphors under electron bombardment.	G. L. Olde E. Branner
Use of a Diode Ring as a Four-Quadrant Multiplier	Rev Scientific Inst November 1959	Operation is analyzed theoretically, and experimental tests are described. An accuracy of 1% is obtainable at input levels up to 150 mv.	R. H. Wilcox
Variable Capacitance Diffused Junction Diodes	Semiconductor Prods November 1959	The space charge layer capacitance has been calculated for some impurity distributions which are characteristic of diffused junction devices.	W. MacDonald D. Schultz J. R. Madigan
Counters Using Single Crystal Barium Titanate Capacitors	Semiconductor Prods November 1959	Uses the single crystal as the key element of the charging circuit and a unijunction transistor as the discharge device.	T. R. Hoffman
A Practical Approach to Transistor Circuit Design	Semiconductor Prods November 1959	Approximate design equation are developed from the basic equivalent circuit of the transistor.	J. D. Long
Solid State Physics at the National Bureau of Standards	Semiconductor Prods November 1959	Outline of program in semiconductor materials and device measurements and investigations at the National Bureau of Standards.	(No Author)
The Determination of Effective Carrier Masses and Optical Constants of Semiconductors	Sov Phys Sol State November 1959	The problem of the experimental determination of carrier masses in semiconductors was examined from the view point of the Fermi Fluid Theory.	V. P. Silin
Diffusion and Recombination During Measurements of the Drift Mobility	Sov Phys Sol State November 1959	Criteria were obtained for the applicability of the simplified formula for calculating the mobility in the case of one-, two-, and three-dimensioned propagation of carriers introduced.	V. N. Dobrovolskii
Disintegration of an Exciton by Phonons in Atomic Semiconductors	Sov Phys Sol State November 1959	Some of the laws governing the disintegration of Mott's exciton into an electron and a hole by means of acoustical phonons are explained.	A. A. Lipnik
Investigation of Growth of an n-type Semiconductor Layer at the Contact Between Cadmium and Selenium	Sov Phys Sol State November 1959	Results of this work can be used to calculate the thickness of the n-type semiconductor layer in a selenium rectifier.	V. A. Dorin B. I. Kuznetsov D. N. Nasledov
Properties and Structure of Ternary Semiconductor Systems Part VI. Electric and Photoelectric Properties of Films of the Sb <sub>2</sub> S <sub>3</sub> -Bi <sub>2</sub> S <sub>3</sub> System	Sov Phys Sol State November 1959	Results obtained are compared with semiconductor properties of large pieces of material from this system. Effect of thermal treatment is considered.	B. T. Kolomiets V. M. Lyubin
Electrical Properties of n-type AlSb	Sov Phys State November 1959	Investigations are made of the specific electrical conductivity, Hall Effect, and thermoelectric power over a wide temperature range.	D. N. Nasledov S. V. Slobodchikov
Electrical and Galvanomagnetic Properties of High Purity In Sb	Sov Phys State November 1959	Results of an investigation of the electrical conductivity and Hall Effect in high purity indium antimonide over a wide temperature range, and in magnetic fields from 60 to 25,000 oersteds.	N. I. Volokobinskaya V. V. Galavanov D. N. Nasledov



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Thermoelectric Properties of Gallium Antimonide (GaSb)	Sov Phys State November 1959	The thermoelectric properties of varying degrees of purity were investigated over the temperature range from $-190$ to $+600^{\circ}\text{C}$ .	A. I. Blum
The Dependence of the Electrical Conductivity of Cuprous Oxide on Oxygen Pressure at High Temperatures. III	Sov Phys State November 1959	The usual vacuum method is unsuitable for such a study. A method for investigation at normal atmospheric pressure and in a specific partial pressure of oxygen was developed.	K. P. Zuev
The Efficiency of Thermoelectric Generators	U S Govt Res Reports September 11 1959 OTS \$2.25 PB 151748	The thermoelectric effects and the efficiency of a thermoelectric generator are described.	J. M. Borrego H. A. Lyden J. Blair
Industrial Preparedness Study on Diffused Semiconductor Devices 5 & 9	U S Govt Res Reports September 11 1959 LC \$3.00 PB 137163	This report includes summary of the design considerations, a description of the manufacturing techniques developed for production and statistical evaluation of state of the art samples.	Motorola, Inc.
Annealing of Radiation Damage in Semiconducting Devices	U S Govt Res Reports September 11 1959 LC \$7.80 PB 140729	Experiments to determine the effects of radiation upon silicon carbide diodes.	V. E. Bryson
Application of PNP Triodes to Magnetic Core Memories	U S Govt Res Reports September 11 1959 LC \$7.80 PB 140728	A shunt current pulser using trinistors ( <i>p-n-p-n</i> triodes) appears promising as an efficient driver. Trinistors have two states ON (low Z) and OFF (high Z).	A. Doty
Design of a Triple-Gated-Coincidence Summing Circuit	U S Govt Res Reports September 11 1959 LC \$13.80 PB 140730	Introduction and outline of the ionization chamber as a source of input to the proposed circuit. The design approach is explained.	D. B. Harris
An Experimental Semiconductor-Diode Parametric Amplifier at S-Band Frequencies	U S Govt Res Reports September 11 1959 LC \$15.30 PB 140922	A parametric amplifier was constructed which used a 1N263 diode as a nonlinear reactance element. The signal frequency was near 2800 mc and the pumping frequency near 5600 mc.	J. V. Boone
The Hall Generator as an Analog Multiplier	U S Govt Res Reports September 11 1959 LC \$7.80 PB 140942	Accuracies of 1% of full scale can easily be attained. This anticipates that a further study of the error problem will materially improve accuracy.	F. H. Miller
Engineering Services on Transistors	U S Govt Res Reports September 11 1959 LC \$12.30 PB 139660	Optional measurements of vapor adsorption on silicon microwave transistor. Boron diffusion by means of a boron trichloride source.	R. J. Archer H. H. Loar Et al
Statistical Plan for the Transistor Inter-Laboratory Experiment	U S Govt Res Reports September 11 1959 LC \$3.30 PB 139516	The object was to determine if the three laboratories participating in this test agreed substantially with respect to their mean level of six test parameters.	A. Lieberman
Research & Development "Alpha-Greater-Than-One" Silicon Devices	U S Govt Res Reports September 11 1959 LC \$4.80 PB 137062	A proposal for achieving a negative resistance diode structure based on point contact transistor action.	CBS-Hytron
Investigation of Microwave Duplexer Switching Mechanisms	U S Govt Res Reports September 11 1959 LC \$6.30 PB 140807	Experiments were performed to determine the free electron removal processes in water vapor, in mixtures of water vapor in helium, or argon gasses alone.	A. A. Dougal K. Rose S. Takeda
Final Engineering Report	U S Govt Res Reports September 11 1959 PB 139508 LC \$16.80	Experiments with materials arsenic doped silicon, electron-irradiated sodium nitrate and electron-irradiated calcite for two-level solid-state maser use have been performed.	J. L. Burkhardt M. S. Cohen H. J. Okoomian
Radio Chemistry Section, Components & Techniques Laboratory	U S Govt Res Reports September 11 1959 LC \$7.80 PB 140826	The report describes the work performed on the studies of a void zone purification apparatus for purifying silicon tetraiodide, and the decomposition of this material to silicon.	C. D. Turner
Solid State Diffusion	U S Govt Res Reports September 11 1959 LC \$4.80 PB 140824	A method for making junctions in silicon by solid state diffusion is presented. Employs a fused silica tube extended through two controlled temperature zones.	I. Berman
Ohmic Contacts and Preliminary Conductivity Measurements on Cadmium Sulphide Whiskers	U S Govt Res Reports September 11 1959 LC \$12.30 PB 140929	A method is developed for handling and putting electrical contacts on Cadmium sulfide whisker crystals. Sputtered platinum contacts are found to have an ohmic response on cadmium sulfide whiskers.	G. K. Hendricks
Research Directed Toward the Investigation of Silicon and Silicon Carbide Surfaces	U S Govt Res Reports September 11 1959 LC \$3.30 PB 140823	Silicon Carbide surfaces cleared in ultra high vacuum by argon-ion bombardment $1000^{\circ}\text{C}$ heating absorbs oxygen at room temperature with a sticking coefficient of the order of 0.01.	J. A. Dillon Jr. R. M. Oman
Lattice Specific Heats Near 0 Degrees K with an Application to Germanium	U S Govt Res Reports September 11 1959 LC \$6.30 PB 140900	Formulas for the low temperature lattice specific heat are developed on the basis of the general adiabatic and harmonic assumptions, independently of special models or numerical procedures.	P. M. Marcus A. J. Kennedy
Investigation of the Surface States on N-Type Germanium	U S Govt Res Reports September 11 1959 LC \$15.30 PB 137271	The studies of semiconductor surface phenomena over the past few years has developed a surface model which postulates the existence of two types of surface states separated by a thin layer of oxide.	R. C. Serrine
Oxygen Impurity in Silicon Single Crystal	U S Govt Res Reports September 11 1959 LC \$3.30 PB 137134	Comparison of the lattice constant and density of "pure" silicon crystal and oxygen contaminated crystal favors the substitutional position of oxygen on the silicon lattice rather than the interstitial.	A. Smakula J. Kalnajs
Studies on the Mechanism of Electroluminescence	U S Govt Res Reports September 11 1959 LC \$9.30 PB 139585	Digests coverage to date in the form of listings, reports, and papers previously submitted on the subjects. Also new material involving variable frequency and electroluminescent powders as semiconductors.	A. Lucyckx J. Vandewavwer Et al
Electronic Properties of Semiconductor Materials	U S Govt Res Reports September 11 1959 LC \$6.30 PB 137070	The lifetime of minority carriers injected either from point-contacts on p-type silicon increases with an increase in temperature above room temperature.	J. Maczuk R. M. Showers B. P. Fabricand
Industrial Preparedness Study on Diffused Semiconductor Devices 5 and 9	U S Govt Res Reports September 11 1959 LC \$3.00 PB 137162	Techniques and modification for fabricating germanium devices to meet the requirements per SD project 509-77 (PROP) for Devices 5 & 9 have been developed.	Motorola, Inc.
Characteristics of Photoconductive Detectors	U S Govt Res Reports September 11 1959 OTS \$7.75 PB 151728	A description of the basic characteristics of photoconductive detectors is given to aid in the interpretation of data obtained in photoconductive research and experimentation.	A. J. Cussen



# PATENT REVIEW\*

## Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Dec. 10, 1957 to Jan. 14, 1958. In subsequent issues, patents issued from Oct. 15, 1957 to date will be presented in a similar manner. After bringing these abstracts up to date, **PATENT REVIEW** will appear periodically, the treatment given to each item being more detailed.

### December 10, 1957

2,815,608 Semiconductor Envelope Sealing Device and Method—L. C. Thompson, Jr. Assignee: Hughes Aircraft Co. The apparatus and method with which a resilient electrode may be placed in electrical contact with the surface of a semiconductor body to provide reproducible electrical characteristics.

2,815,179 Transistor Push-Pull Amplifier—R. Gittleman, J. Tellerman. Assignee: American Bosch Arma Corp. A circuit in which two similar type junction transistors are connected in push-pull combination to provide a Class A circuit operating from a single ended source.

2,816,220 Frequency Converter—H. C. Goodrich. Assignee: Radio Corporation of America. A semiconductor frequency converter in which the oscillatory wave is developed without utilizing an external feedback path said converter providing substantial conversion power gain.

2,816,228 Semiconductor Phase Shift Oscillator and Device—H. Johnson. Assignee: Radio Corporation of America. A device comprising a body of semiconductor material having alternate zones of opposite conductivity type, a semiconductor delay line integral with one of these zones, said delay line including a plurality of series connected filaments of semiconductor material and  $p$ - $n$  junction portions.

2,816,230 Blocking Oscillator Circuit—J. E. Lindsay. Assignee: Radio Corporation of America. A blocking oscillator circuit comprising a transistor, regenerative feedback means between the collector and base electrodes, a rectifying device connected with the emitter, and a time-constant network for the circuit connected with the rectifying device.

2,816,232 Germanium for Infra Red Detector—E. Burstein. Assignee: United States of America (Navy Department). A device for detecting long infra-red radiation, said device consisting of a specimen of germanium having a zinc impurity concentration between  $10^{13}$  and  $10^{18}$  atoms of zinc per cubic centimeter, means for maintaining the specimen at temperatures near  $0^\circ\text{K}$ ., and means for determining the energy level of the specimen.

2,816,234 Radiant Energy Detector—S. G. Ellis. Assignee: Radio Corporation of America. A method for the detection of radiant energy comprising the orientation of a photosensitive crystal such that

the glancing angle of incident radiation is the Bragg Angle and recording a change in a physical characteristic of said crystal in response to said radiant energy.

2,816,237 System for Soupling Signals Into and Out of Flip-Flops—D. H. Hagerman. Assignee: Hughes Aircraft Co. A system adapted to couple signals into and out of a transistor flip-flop and which will allow a single slip-flop to supply intelligence signals simultaneously to 25 or 30 gates.

2,816,238 Electronic Switches—G. Elliot. Assignee: General Dynamics Corp. An electronic switch comprising a semiconductor device having first and second junctions in series with the circuit to be closed, said switch being actuated by application of suitable potentials to a control electrode of the semiconductor device.

2,816,260 Regulated D.C. Power Supply—D. G. Scorgie. Assignee: United States of America (Navy Dept.). A voltage regulator comprising two full wave magnetic amplifiers having two cores saturated alternately upon successive half cycles of an alternating voltage, and a control circuit including a diode that is poled so that current will flow when the zener breakdown voltage is exceeded.

2,816,283 Semiconductor Null Detector—M. C. Steele. Assignee: Radio Corporation of America. A null detector comprising a semiconductor double diode in which a pair of zones of one conductivity type is separated by, and contiguous with, a zone of the opposite conductivity type; and in which the middle zone can be greater than the diffusion length of the carriers of the semiconductor.

### December 17, 1957

2,816,847 Method of Fabricating Semiconductor Signal Translating Devices—W. Shockley. Assignee: Bell Telephone Laboratories. A method of producing a semiconductor body having a zone of conductivity type opposite to that of the bulk of the body, said method consisting of applying to one face of a germanium or silicon body a coating of conductivity type determining impurity, directing an electron beam against said coating to effect diffusion of said impurity into the material, and forming a predetermined configuration of opposite conductivity type upon said surface.

2,816,850 Semiconductive Translator—H. E. Naring. Assignee: Bell Telephone Laboratories. A means of inhibiting the formation of deleterious leakage paths in semiconductor devices of the junction type.

2,816,964 Stabilizing Means for Semiconductor Circuits—L. J. Giaccolletto. Assignee: Radio Corporation of America. A translating circuit in which the emitter current of a stabilized transistor is maintained at a constant value despite circuit or environmental changes.

2,817,046 Filament Bar Casing and Method of Making Same—S. I. Weiss. Assignee: None. A casing for a filament bar of semiconductive material comprising a cup shaped glass housing having a mouth, a glass member, a cavity defined between the base member and the casing, a metal member embedded in solidified powdered glass and extending around the cavity, a pair of holders in the housing and a bar of semiconductor material positioned at its ends on said holder.

2,817,047 Dry Contact Rectifiers—E. A. Richards, L. J. Ellison. Assignee: International Standard Electric Corp. A selenium rectifier assembly comprised of rectangular plates pierced with a row of holes along each major edge, and means for stacking a number of plates with intervening spacing and electrical bus bars between parallel pairs of edges of each adjacent pair of plates.

2,817,048 Transistor Arrangement—E. Thuermel, K. Sieberty, H. Henker, D. Enderlein. Assignee: Siemens and Halske Aktiengesellschaft (Germany). A transistor arrangement comprising a casing, an electrode in good heat conducting connection thereto, an insulating layer between the transistor and the casing, said layer forming the dielectric of a capacitor, said casing forming one coating of said capacitor, and a metallic part forming the other coating of the capacitor.

2,817,057 Resistive Reactor—H. E. Hollman. Assignee: None. A device that utilizes a nonlinear impedance to control currents over a wide frequency range.

### December 24, 1957

2,817,607 Method of Making Semiconductor Bodies—D. A. Jenny. Assignee: Radio Corporation of America. A method of forming a  $p$ - $n$  rectifying junction within a semiconductor body by diffusion of an impurity-yielding material into the body at a temperature below the melting points of both the body and the impurity yielding material.

2,817,608 Melt-Quench Method of Making Transistor Devices—J. I. Pankove. Assignee: Radio Corporation of America. A method of making semiconductor devices by melting a longitudinal portion of a crystalline semiconductive filament, maintaining another longitudinal portion of

\*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.



said filament in its solid state, and quenching the melted portion by refreezing at a cooling rate of at least 500°C per second so that solidification starts at the unmelted cool end and proceeds to the other end, thus forming a pair of spaced parallel *p-n* rectifying barriers.

2,817,609 Alkali Metal Alloy Agents for Auto-Fluxing in Junction Forming—W. P. Waters. Assignee: Hughes Aircraft Co. A method of fusing a metal alloy pellet to a region of an active impurity-doped semiconductor starting crystal, said alloy acting as its own fluxing agent.

2,817,613 Semiconductor Devices with Alloyed Conductivity-Type Determining Substance—C. W. Mueller. Assignee: Radio Corporation of America. A device having at least two *p-n* junctions in which the conductivity of the materials between the junctions is greater in an area adjacent to one junction than in an area adjacent to the other junction, and in which said junctions have different characteristics.

2,817,715 Amplifier Circuit Having Linear and Non Linear Amplification Ranges—F. G. Blake. Assignee: California Research Corp. Means for suppressing the peaks of a voltage wave entering an amplifier and means for expanding the peaks at the output to reproduce the wave shape.

2,817,761 Transistor Oscillator Circuits—H. E. Hollman. Assignee: None. A transistor oscillator including a transistor that exhibits non-linear transfer characteristics in response to a periodically varying applied voltage, and means for feeding back a portion of the oscillatory energy developed by a resonator, said feed-back occurring in a nonlinear fashion.

2,817,771 Pulse Height Discriminator—J. M. Barnothy. Assignee: Research Corp. A discriminator unit that may be transferred between the highest and lowest channel of an amplitude channelizer without requiring alteration or calibration.

2,817,772 Pulse Switching Apparatus—W. S. Lee. Assignee: United States of America (Navy Dept.). Apparatus having a single input and a plurality of outputs selectively controlled by a plurality of crystals, one of which is permitted to pass the input signal to its respective output in accordance with a switch position selected by a remotely placed switch.

2,817,797 Rectifier—W. J. Coyle. Assignee: United-Carr Fastener Corp. A hermetically sealed rectifier assembly which has internal spring means bearing rectifier plates into position and completing an electric circuit thereto.

2,817,798 Semiconductors—D. A. Jenny. Assignee: Radio Corporation of America. A device consisting of a single crystal body of an alloy of germanium and at least 1% semiconducting silicon, and at least one rectifying electrode connected to said body.

2,817,799 Semiconductor Devices Employing Cadmium Telluride—D. A. Jenny. Assignee: Radio Corporation of America. A device comprising a body of semiconductive cadmium telluride having a *p*-type region, the conductivity of which is determined by trace amounts of impurity centers of the atoms of at least one element of group IIIa and Va of the periodic system.

## December 31, 1957

2,818,361 Heat Treatment of Silicon Transistor Bars—R. E. Anderson, W. L. Medlin. Assignee: Texas Instruments. A method of making transistor bars by forming a grown silicon junction bar having an *n*-type antimony-doped collector portion, a thin *p*-type aluminum doped base portion, an *n*-type arsenic doped emitter portion; and heating said bar to about 500°C for a period between 15 minutes and two hours.

2,818,470 Compensated Transistor Circuit—A. Busala, L. A. Meacham. Assignee: Bell Telephone Laboratories. A transistor circuit that maintains the transmission level of a plurality of telephone subscribers substantially constant regardless of the loop length and the range of loop currents.

2,818,531 Electroluminescent Image Device—S. C. Peek, Jr. Assignee: Sylvania Electric Products, Inc. An image producing device comprising an electroluminescent phosphor layer, a series of conducting lines on one side of said layer, another series of lines on the opposite sides of the layer and at an angle to the first set of lines, and a rectifier connected to each of the lines in at least one of said series.

2,818,536 Point Contact Semiconductor Devices and Methods of Making Same—J. N. Carman, Jr., E. E. Maiden. Assignee: Hughes Aircraft Co. In a point contact device, a whisker element comprising a resilient molybdenum wire pointed at one end, and a layer of elemental indium plated over the pointed end.

2,818,537 Germanium Diodes—H. Wolfson. Assignee: International Standard Electric Corp. A crystal rectifier comprising a crystal of germanium, a low-resistance-contact base electrode, a thin contact film of an alloy of germanium and lead or tin, said film covering a part of the crystal surface, and a catwhisker electrode making contact with said film.

## January 7, 1958

2,819,191 Method of Fabricating a *P-N* Junction—C. S. Fuller. Assignee: Bell Telephone Laboratories. A method of producing stable *p*-type silicon which comprises heating said material to between 350 and 500°C for 1 to 48 hours and then heating said material to between 900 and 1300°C for more than 15 hours.

2,819,352 Transistor Magnetic Amplifier Circuit—C. B. Houck, Jr. Assignee: General Precision Laboratories, Inc. An amplifier comprising an *n-p-n* junction transistor and a *p-n-p* junction transistor, having their connector electrodes connected to opposite terminals of a potential source, a pair of saturable core reactors, and a signal input circuit connected between a common emitter terminal and the base electrodes of said transistors.

2,819,414 Radio Active Battery Employing Stacked Semiconducting Devices—R. L. Sherwood, P. Rappaport. Assignee: Radio Corporation of America. A primary source of electrical energy comprising a plurality of aligned spaced junction type semi-conducting devices, an electrically conductive plastic between adjacent devices, and a radioactive source positioned to irradiate all of said devices so as to generate a potential.

2,819,433 Selenium Rectifiers and the Method of Making the Same—C. Scudder. Assignee: Syntrol Co. A selenium recti-

fier comprising a conducting sheet having approximately fifty or more very thin superimposed layers of crystalline selenium, a blocking layer on the topmost selenium layer, and a counter electrode on the blocking layer.

2,819,434 Rectifier Stack—M. J. Mattheyses. Assignee: International Telephone and Telegraph Company. A rectifier assembly having several elements and several spaced cooling fins, the latter being arranged so that a rectifier element mounted on one fin protrudes through an opening in the adjacent fin.

2,819,436 Method of Making Dry Contact Rectifiers, Particularly Selenium Rectifiers—H. A. Bartels. Assignee: International Standard Electric Corporation. A rectifier comprising a base electrode, a semiconductive layer, and a counter electrode consisting of a nonconductive lacquer having distributed small metal particles therein, said particles constituting a multipoint rectifier through a barrier layer formed by the non-conductive lacquer.

## January 14, 1958

2,819,513 Semiconductor Assembly and Method—S. T. Martin. Assignee: None. A method of mounting semiconductors on bases by interposing separating pins between the individual members of a cluster of base pins to provide a configuration of four-fold symmetry and fastening a semiconductor sheet to the ends of said base pins.

2,819,990 Treatment of Semiconductive Bodies—C. S. Fuller, H. Reiss. Assignee: Bell Telephone Laboratories. A semiconductor device comprising a germanium body having one portion which includes lithium and an acceptor impurity whose ions have a plural negative charge in germanium, said acceptor forming stable ion-pair bonds with the lithium.

2,820,135 Method For Producing Electrical Contact to Semiconductor Devices—K. A. Yamakawa. Assignee: Pacific Semiconductors, Inc. A method consisting of bringing the end of a whisker element into contact with a body of solid solder, passing a current through said whisker to weld said whisker to said body, and welding the whisker with the body of solder attached thereto to a semiconductor crystal.

2,820,143 Transistor Phase Detector—G. O. D'Nelly N. B. Fjeldsted. Assignee: Hughes Aircraft Company. A transistor phase detector for producing direct current voltage levels in response to the phase relationships between applied reference and comparison signals.

2,820,145 Transistor Oscillator Circuit Arrangement—E. Wolfendale. Assignee: North American Phillips Company, Inc. In a transistor circuit, a transistor driven at a frequency so high that a phase displacement occurs between the base current and the emitter current so that the base input impedance has negative resistance component.

2,820,151 Parallel Magnetic Complementers—W. F. Steagall. Assignee: Sperry Rand Corporation. An input circuit and energy source for providing complementing action in parallel magnetic amplifiers.

[To Be Continued]



# CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between Nov. 1, 1959 and Dec. 31, 1959

This is a partial listing and will be continued in the April issue.

## MANUFACTURERS

ARA— Advanced Research Associates, Inc.  
 AEG— Allgemeine Elektricitäts-gesellschaft  
 AMP— Ampere Electronic Corp.  
 AEI— Associated Electrical Industries LTD. and Siemens Edison Swan.  
 BEN— Bendix Aviation Corp.  
 BOG— Bogue Electric Mfg. Co.  
 CBS— CBS-Electronics  
 CRY— Crystalonics, Inc.  
 CSF— Compagnie Generale  
 CTP— Clevite Transistor Products, Inc.  
 DEL— Delco Radio Div., General Motors Corp.  
 FSC— Fairchild Semiconductors Corp.  
 FTHF— French Thomson-Houston Semiconductor Dept.  
 GEGB— General Electric Co., Ltd.  
 GE— General Electric Co.  
 GEM— Great Eastern Mfg. Co.  
 GTC— General Transistor Corp.  
 HSD— Hoffman Semiconductor Div.  
 HUG— Hughes Aircraft Co.  
 HVB— Hivac Ltd.  
 IND— Industro Transistor Corp.  
 LCTF— Laboratoire Central de Telecommunications  
 MIFI— Microfarad (Italy)  
 MIN— Minneapolis-Honeywell Regulator Co.  
 MOT— Motorola, Inc.

## (In Order of Code Letters)

MUL— Mullard Ltd.  
 NAC— National Semiconductor Corp.  
 NTLB— Newmarket Transistors Ltd.  
 PSI— Pacific Semiconductors, Inc.  
 PHI— Philco Corp., Landsdale Tube Co.  
 RAY— Raytheon Co.  
 RCA— Radio Corp. of America, Semiconductor Div.  
 RHE— Rheem Semiconductor Corp.  
 SIE— Siemens & Halske Aktiengesellschaft  
 SIL— Silicon Transistor Corp.  
 SONY— Sony Corp.  
 SPE— Sperry Gyroscope Co.  
 SPR— Sprague Electric Co.  
 SYL— Sylvania Electric Products Inc.  
 STCB— Standard Telephone & Cables, Ltd.  
 TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke  
 TRA— Transitron Electronic Corp.  
 TFKG— Telefunken Ltd.  
 TI— Texas Instruments  
 THB— Texas Instruments Ltd.  
 TUN— Tung-Sol Electric, Inc.  
 UST— U. S. Transistor Corp.  
 WEC— Western Electric Co., Inc.  
 WEST— Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

GENERAL TRANS.: 2N327A, 2N328A, 2N578 thru 2N582, 2N1025, 2N1026, 2N1034, 2N1035, 2N1090, 2N1091  
 MICROFARAD: This company is licensed by Compagnie Generale de T.S.F. and manufactures all types produced by Compagnie Generale de T.S.F.

MOTOROLA: 2N705, 2N710

NATIONAL SEMI.: 2N560, 2N696, 2N697, 2N702, 2N703, 2N715, 2N716, 2N1060, 2N1234

RAYTHEON: 2N395, 2N396, 2N397, 2N1090, 2N1091

SYLVANIA: 2N404, 2N417, 2N428, 2N644, 2N1000, 2N1302, 2N1304, 2N1306, 2N1308

TYPE NO.	USE { See Code Below }	TYPE { See Code Below }	MAT	Max. Ratings @ 25° C				Typical Characteristics				MFR. See code at start of charts
				P <sub>c</sub> (mw)	DERAT ING °C/W	V <sub>ce</sub>	V <sub>ce</sub>	f <sub>β</sub> (mc)	Gain			
									PARAMETER and (condition)	VALUE		
2N377A	5	NPNA	Ge	150	.50	40	40	6.0	$h_{FE}:I_C-$	30ma	40	SYL
2N385A	5	NPNA	Ge	150	.50	40	40	7.0	$h_{FE}:I_C-$	30ma	70	SYL
2N388A	5	NPNA	Ge	150	.50	40	40	8.0	$h_{FE}:I_C-$	30ma	90	SYL
2N695	5	PNPMe	Ge	75	1000	15	15	250†	$h_{FE}:I_C-$	150ma	40	MOT
2N698	3,4,5	NPNMe	Si	2000	75	120	80	180	$h_{FE}:I_C-$	150ma	30∅	FSC
2N700	2	PNPMe	Ge	75	1000	25	20		$h_{FE}:I_C-$	10ma	12∅	FSC
2N707	3,4,5	NPNMe	Si	1000	150	56	28	400	$h_{FE}:I_C-$	150ma	40∅	FSC
2N717	3,4,5	NPNMe	Si	1500	100	60	40	150	$h_{FE}:I_C-$	150ma	75∅	FSC
2N718	3,4,5	NPNMe	Si	1500	100	60	40	150	$h_{FE}:I_C-$	10ma	20min	TRA
2N728	5	NPN	Si	500		15	15	150	$h_{FE}:I_C-$	10ma	20min	TRA
2N729	5	NPN	Si	500		30	30	150	$h_{FE}:I_C-$	10ma	25	MOT
2N741	2	Me	Ge	150	500	15	15	360†	$h_{FE}:I_C-$	10ma	35	NAC
2N742	5	PNPD	Si	600	210	60	60	100	$h_{FE}:I_C-$	10ma	20	RAY
2N745	5	D	Si	200	750	45		10	$h_{FE}:I_C-$	10ma	45	RAY
2N746	5	D	Si	200	750	45		20	$h_{FE}:I_C-$	10ma	30	RAY
2N747	5	D	Si	200	750	25	25	25	$h_{FE}:I_C-$	10ma	20	RAY
2N748	5	D	Si	200	750	30	30	25	$h_{FE}:I_C-$	10ma	7db	RAY
2N749	4	D	Si	200	750	45	45	50	$h_{FE}:I_C-$	10ma	4db	RAY
2N750	4	D	Si	200	750	50	50	25	PG at 6.0Mc		2.2db	RAY
2N751	4	D	Si	200	750	20	20	25	PG at 6.0Mc			RAY



TYPE NO.	USE { See Code Below }	TYPE { See Code Below }	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P <sub>c</sub> (mw)	DERAT ING °C/W	V <sub>CB</sub>	V <sub>CE</sub>	f <sub>αβ</sub> (mc)	Gain		
									PARAMETER and (condition)	VALUE	
2N1018	5	A	Ge	150	350	30	8.0	25	$h_{FE}: I_B - 1.0ma$	140	RAY
2N1177	4	PNPD	Ge	80		30		140	$h_{FE}: I_B - 1.0ma$	100	RCA
2N1178	4	PNPD	Ge	80		30		140	$h_{FE}: I_C - 1.0ma$	40	RCA
2N1179	4	PNPD	Ge	80		30		140	$h_{FE}: I_C - 1.0ma$	80	RCA
2N1180	4	PNPD	Ge	80		30		100	$h_{FE}: I_C - 1.0ma$	80	RCA
2N1213	5	PNPMe	Ge	75		25	25				RCA
2N1214	5	PNPMe	Ge	75		25	25				RCA
2N1215	5	PNPMe	Ge	75		25	25				RCA
2N1216	5	PNPMe	Ge	75		25	25				RCA
2N1314	3	PNPA	Ge		1.0	32	32	.15	$h_{FE}: I_E - 1.0A$	33	AMP
2N1315	3	PNPA	Ge		1.0	32	32	.30	$h_{FE}: I_E - 1.0A$	64	AMP
2N1366	4	A	Ge	150	350	20	18	10	$h_{FE}: I_C - 1.0ma$	70	RAY
2N1367	4	A	Ge	150	350	20	18	10	$h_{FE}: I_C - 1.0ma$	70	RAY
2N1439	2	PNPA	Si	400	440	50	40	1.0	$h_{FE}: 6.0V, 1.0ma$	9.0	NAC
2N1443	2	PNPA	Si	400	440	50	30	1.0	$h_{FE}: 6.0V, 1.0ma$	70	NAC
2N1470	3	D	Si	5500	3.0	60	60	1.0	$h_{FE}: I_C - 1.0A$	15	RAY
2N1515	4,5	PNPAD	Ge	50	600	20		70#	PG at $c_{.45Mc}$	35	AMP
2N1516	4,5	PNPAD	Ge	60	500	20		70#	PG at $.45Mc$	57	AMP
2N1517	4,5	PNPAD	Ge	70	500	20		100#	PG at 100Mc	11	AMP
2N1518	3	PNPA	Ge		.80	50	40	4KcΔ	$h_{FE}: I_C - 25A$	12min	DEL
2N1519	3	PNPA	Ge		.80	80	60	4KcΔ	$h_{FE}: I_C - 25A$	12min	DEL
2N1520	3	PNPA	Ge		.80	50	40	4KcΔ	$h_{FE}: I_C - 35A$	12min	DEL
2N1521	3	PNPA	Ge		.80	80	60	4KcΔ	$h_{FE}: I_C - 35A$	12min	DEL
2N1522	3	PNPA	Ge		.80	50	40	4KcΔ	$h_{FE}: I_C - 50A$	12min	DEL
2N1523	3	PNPA	Ge		.80	80	60	4KcΔ	$h_{FE}: I_C - 50A$	12min	DEL
2N1528	4	D	Si	150	1000	25	25	20	PG at 6.0Mc	4db	RAY
2N1529	3	PNP	Ge	90W	.80	40	30	10KcΔ	$h_{FE}:$	30	MOT
2N1530	3	PNP	Ge	90W	.80	60	45	10KcΔ	$h_{FE}:$	30	MOT
2N1531	3	PNP	Ge	90W	.80	80	60	10KcΔ	$h_{FE}:$	30	MOT
2N1532	3	PNP	Ge	90W	.80	100	75	10KcΔ	$h_{FE}:$	30	MOT
2N1533	3	PNP	Ge	90W	.80	120	90	10KcΔ	$h_{FE}:$	30	MOT
2N1534	3	PNP	Ge	90W	.80	40	30	8.5KcΔ	$h_{FE}:$	50	MOT
2N1535	3	PNP	Ge	90W	.80	60	45	8.5KcΔ	$h_{FE}:$	50	MOT
2N1536	3	PNP	Ge	90W	.80	80	60	8.5KcΔ	$h_{FE}:$	50	MOT
2N1537	3	PNP	Ge	90W	.80	100	75	8.5KcΔ	$h_{FE}:$	50	MOT
2N1538	3	PNP	Ge	90W	.80	120	90	8.5KcΔ	$h_{FE}:$	50	MOT
2N1539	3	PNP	Ge	90W	.80	40	30	4KcΔ	$h_{FE}:$	75	MOT
2N1540	3	PNP	Ge	90W	.80	60	45	4KcΔ	$h_{FE}:$	75	MOT
2N1541	3	PNP	Ge	90W	.80	80	60	4KcΔ	$h_{FE}:$	75	MOT
2N1542	3	PNP	Ge	90W	.80	100	75	4KcΔ	$h_{FE}:$	75	MOT
2N1543	3	PNP	Ge	90W	.80	120	90	4KcΔ	$h_{FE}:$	75	MOT
2N1544	3	PNP	Ge	90W	.80	40	30	4KcΔ	$h_{FE}:$	110	MOT
2N1545	3	PNP	Ge	90W	.80	60	45	4KcΔ	$h_{FE}:$	110	MOT
2N1546	3	PNP	Ge	90W	.80	80	60	4KcΔ	$h_{FE}:$	110	MOT
2N1547	3	PNP	Ge	90W	.80	100	75	4KcΔ	$h_{FE}:$	110	MOT
2N1548	3	PNP	Ge	90W	.80	120	90	4KcΔ	$h_{FE}:$	110	MOT
2N1549	3	PNP	Ge	90W	.80	40	30	10KcΔ	$h_{FE}:$	20	MOT

NOTATIONS		
Under Use	Under Type	Under fab
1- Low power a-f equal to or less than 50 mw	7- Photo	A - Alloyed
2- Medium power a-f > 50 mw and equal to or less than 500 mw	8- Mixer	D - Diffused or Drift
3- Power > 500 mw	9- Local Oscillator	F - Fused
4- r-f/i-f	10- Revised Spec.	G - Grown
5- Switching and Computer	11- Chopper	H - Hook Collector
6- Low Noise	11- Matched Pair	M - Microalloy
		Me - Mesa
		O - Other
		S - Surface Barrier
		UNI - Unijunction Transistor
		Y - Symmetrical
		I - Tetrode
		* Maximum Frequency
		# Figure of Merit
		Δ f <sub>e</sub>
		∅ Minimum
		F <sub>T</sub> = Gain Bandwidth Product $h_{FE} \times h_{fE}$
		Under Derating
		∅ - Infinite heat sink



# CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE { See Code Below }	TYPE { See Code Below }	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at end of chart
				P <sub>c</sub> (mw)	DERAT ING °C/W	V <sub>cb</sub>	V <sub>ce</sub>	f <sub>nβ</sub> (mc)	Gain		
									PARAMETER and (condition)	VALUE	
2N1550	3	PNP	Ge	90W	.80	68	45	10KcΔ	h <sub>FE</sub> :	20	MOT
2N1551	3	PNP	Ge	90W	.80	80	60	10KcΔ	h <sub>FE</sub> :	20	MOT
2N1552	3	PNP	Ge	90W	.80	100	75	10KcΔ	h <sub>FE</sub> :	20	MOT
2N1553	3	PNP	Ge	90W	.80	40	30	6KcΔ	h <sub>FE</sub> :	45	MOT
2N1554	3	PNP	Ge	90W	.80	68	40	6KcΔ	h <sub>FE</sub> :	45	MOT
2N1555	3	PNP	Ge	90W	.80	80	60	6KcΔ	h <sub>FE</sub> :	45	MOT
2N1556	3	PNP	Ge	90W	.80	100	75	6KcΔ	h <sub>FE</sub> :	45	MOT
2N1557	3	PNP	Ge	90W	.80	40	30	5KcΔ	h <sub>FE</sub> :	75	MOT
2N1558	3	PNP	Ge	90W	.80	60	40	5KcΔ	h <sub>FE</sub> :	75	MOT
2N1559	3	PNP	Ge	90W	.80	80	60	5KcΔ	h <sub>FE</sub> :	75	MOT
2N1560	3	PNP	Ge	90W	.80	100	75	5KcΔ	h <sub>FE</sub> :	75	MOT
2N1561	3	Me	Ge	3WØ	25	25	25	500†	h <sub>fe</sub> :	10db	MOT
2N1562	3	Me	Ge	3WØ	25	25	25	500†	h <sub>fe</sub> :	10db	MOT
2N1609	3	PNPA	Ge		15	80	60	17KcΔ	h <sub>FE</sub> :I <sub>C</sub> -.50A	10min	DEL
2N1610	3	PNPA	Ge		15	80	60	15KcΔ	h <sub>FE</sub> :I <sub>C</sub> -.50A	25min	DEL
2N1611	3	PNPA	Ge		15	60	40	17KcΔ	h <sub>FE</sub> :I <sub>C</sub> -.50A	10min	DEL
2N1612	3	PNPA	Ge		15	60	40	15KcΔ	h <sub>FE</sub> :I <sub>C</sub> -.50A	25min	DEL
2N1623	2	A	Si	250	540	20	20	.10	h <sub>FE</sub> :I <sub>C</sub> -1.0ma	10	RAY
2SA121	4	PNPG	Ge	15		15	15	100	PG at 10Mc	24db	SONY
2SA122	4	PNPG	Ge	15		15	15	100	PG at 10Mc	30db	SONY
2SA123	4	PNPG	Ge	15		15	15	100	PG at 10Mc	35db	SONY
2SA124	4	PNPG	Ge	15		15	15	120	PG at 10Mc	31db	SONY
2SA125	5	PNPG	Ge	15		15	15	120	PG at 10Mc	28db	SONY
2SB48	2	PNPA	Ge	140	300	16	16	2.5	h <sub>FE</sub> :I <sub>C</sub> -20ma	43	SONY
2SB49	2	PNPA	Ge	140	300	16	16	3.0	h <sub>FE</sub> :I <sub>C</sub> -20ma	83	SONY
2SB50	2	PNPA	Ge	140	300	16	16	3.5	h <sub>FE</sub> :I <sub>C</sub> -20ma	131	SONY
2SB51	2	PNPA	Ge	200	300	30	20	2.0	h <sub>FE</sub> :I <sub>C</sub> -20ma	43	SONY
2SB52	2	PNPA	Ge	200	300	30	20	3.0	h <sub>FE</sub> :I <sub>C</sub> -20ma	83	SONY
2SB53	5	PNPA	Ge	200	300	30	30	3.0	h <sub>FE</sub> :I <sub>C</sub> -20ma	70	SONY
2SB140	5	PNPA	Ge	12W	5.0	40	40	7KcΔ	h <sub>FE</sub> :I <sub>C</sub> -1.0A	74	SONY
2SB141	5	PNPA	Ge	12W	5.0	60	60	7KcΔ	h <sub>FE</sub> :I <sub>C</sub> -1.0A	74	SONY
2SB142	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h <sub>FE</sub> :I <sub>C</sub> -1.0A	24	SONY
2SB143	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h <sub>FE</sub> :I <sub>C</sub> -1.0A	37	SONY
2SB144	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h <sub>FE</sub> :I <sub>C</sub> -1.0A	75	SONY
2SB145	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h <sub>FE</sub> :I <sub>C</sub> -1.0A	37	SONY
2SB146	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h <sub>FE</sub> :I <sub>C</sub> -1.0A	75	SONY
2SC73	4	NPNG	Ge	30		15	15	20	PG at 2.0Mc	27db	SONY
2SC75	4	NPNG	Ge	30		15	15	10	PG at 2.0Mc	41db	SONY
2SC76	4	NPNG	Ge	30		15	15	10	PG at 2.0Mc	37db	SONY
2SC77	4	NPNG	Ge	30		15	15	10	PG at 2.0Mc	32db	SONY
2SC78	5	NPNG	Ge	30		15	15	20	PG at 2.0Mc	26db	SONY
2SD61	5	NPNA	Ge	100	600	30	25	1.0	h <sub>FE</sub> :I <sub>C</sub> -10ma	50	SONY

## NOTATIONS

### Under Use

- 1- Low power a-f equal to or less than 50 mw
- 2- Medium power a-f > 50 mw and equal to or less than 500 mw
- 3- Power > 500 mw
- 4- r-f/1-f
- 5- Switching and Computer
- 6- Low Noise
- 7- Photo
- 8- Mixer
- 9- Local Oscillator
- 10- Chopper
- 11- Matched Pair

### Under Type

- A - Alloyed
- D - Diffused or Drift
- F - Fused
- G - Grown
- H - Hook Collector
- M - Microalloy

### Under Gain Value

∅ - Pulsed

### Under fab

- Me - Mesa
- O - Other
- S - Surface Barrier
- UNI - Unijunction Transistor
- Y - Symmetrical
- I - Tetrode

- \* Maximum Frequency
- # Figure of Merit
- Δ f<sub>e</sub>
- ∅ Minimum
- F<sub>T</sub> = Gain Bandwidth Product h<sub>fe</sub> × f<sub>hfe</sub>

### Under Derating

∅ - Infinite heat sink



# CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE See Code Below	TYPE See Code Below	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P <sub>c</sub> (mw)	DERAT ING °C/W	V <sub>CB</sub>	V <sub>CE</sub>	f <sub>αβ</sub> (mc)	Gain		
									PARAMETER and (condition)	VALUE	
2SD62	5	NPNA	Ge	100	600	30	25	1.0	$h_{FE}:I_C - 10ma$	50	SONY
2SD63	2	NPNA	Ge	100	600	25	20	1.0	$h_{FE}:I_C - 10ma$	50	SONY
2SD64	1	NPNA	Ge	50	625	25	20	1.0	$h_{FE}:I_C - 10ma$	100	SONY
2SD65	2	NPNA	Ge	80	625	25	20	1.0	$h_{FE}:I_C - 10ma$	50	SONY
2SD66	2	NPNA	Ge	80	625	25	20	.80	$h_{FE}:I_C - 10ma$	25	SONY
B1154	5	A	Ge	400	1500	60	55	1.5	$h_{FE}:I_C - 10ma$	60	BEN
CK4A	5	A	Ge	80	750	30	24	12	$h_{FE}:I_C - .40ma$	60	RAY
CK13A	4	A	Ge	80	750	30	18	2.5	$h_{FE}:I_C - 1.0ma$	30	RAY
CK14A	4	A	Ge	80	750	30	15	7.0	$h_{FE}:I_C - 1.0ma$	60	RAY
CK16A	4	A	Ge	80	750	30	12	10	$h_{FE}:I_C - 1.0ma$	80	RAY
CK17A	4	A	Ge	80	750	30	10	18	$h_{FE}:I_C - 1.0ma$	140	RAY
CK22A	2	A	Ge	80	750	35	20	1.2	$h_{FE}:I_C - 1.0ma$	90	RAY
CK25A	5	A	Ge	80	750	30	30	4.0	$h_{FE}:I_C - 1.0ma$	30	RAY
CK26A	5	A	Ge	80	750	30	25	6.0	$h_{FE}:I_C - 1.0ma$	40	RAY
CK27A	5	A	Ge	80	750	30	20	11	$h_{FE}:I_C - 1.0ma$	55	RAY
CK28A	5	A	Ge	80	750	30	15	17	$h_{FE}:I_C - 1.0ma$	80	RAY
CK64A	2	A	Ge	80	750	45	29	.80	$h_{FE}:I_C - 1.0ma$	22	RAY
CK65A	2	A	Ge	80	750	45	24	1.0	$h_{FE}:I_C - 1.0ma$	45	RAY
CK66A	2	A	Ge	80	750	35	20	1.2	$h_{FE}:I_C - 1.0ma$	90	RAY
CK67A	2	A	Ge	80	750	35	15	1.5	$h_{FE}:I_C - 1.0ma$	180	RAY
CK798	2	A	Si	250	540	150	80	.10	$h_{FE}:I_C - 1.0ma$	20	RAY
CK799	2	A	Si	250	540	150	125	.10	$h_{FE}:I_C - 1.0ma$	10	RAY
CK800	2	A	Si	200	540	150	125	.10	$h_{FE}:I_C - 1.0ma$	20	RAY
GT31	2,5	PNPA	Ge	125	400	15	15	.80	$h_{FE}:I_C - 1.0ma$	20	AEI
GT32	2,5	PNPA	Ge	125	400	15	15	.90	$h_{FE}:I_C - 1.0ma$	40	AEI
GT33	2,5	PNPA	Ge	125	400	15	15	1.0	$h_{FE}:I_C - 1.0ma$	60	AEI
GT41	4,5	PNPA	Ge	100	500	15	15	4.0	$h_{FE}:I_C - 1.0ma$	30	AEI
GT42	4,5	PNPA	Ge	100	500	15	15	6.0	$h_{FE}:I_C - 1.0ma$	60	AEI
GT43	4,5	PNPA	Ge	100	500	15	15	9.0	$h_{FE}:I_C - 1.0ma$	110	AEI
GT1624	5	NPNA	Ge	120	.50	40	25	1.5	$h_{FE}:I_C - 1.0ma$	70	GTC
GT1658	5	NPNA	Ge	150	.50	25		6.0	$h_{FE}:I_C - 20ma$	60	GTC
GT1665	5	PNPA	Ge	120	.50	100		10*	$h_{FE}:I_C - 10ma$	25	GTC
NS100	2	PNPA	Si	400	440	50	15	1.0	$h_{FE}:I_C - 6.0V, 1.0ma$	40	NAC
NS101	2	PNPA	Si	400	440	50	30	1.0	$h_{FE}:I_C - 6.0V, 1.0ma$	18	NAC
NS200	5	PNPD	Si	600	290	25	20	200	$h_{FE}:I_C - 5.0V, 10ma$	15	NAC
NS300	4	PNPD	Si	600	290	85	45	200	$h_{FE}:I_C - 10V, 1.0ma$	25	NAC
ST440	3	NPND	Si	60W	2.08	60	60	8.0	$h_{FE}:I_C - 12V, 1.0A$	10	TRA
ST450	3	NPND	Si	60W	2.08	60	60	8.0	$h_{FE}:I_C - 12V, 1.0A$	10	TRA
ST3042	10	NPN	Si	50		1.0	1.0	1.0	$h_{FE}:I_C - 12V, 1.0A$		TRA
ST3043	10,11	NPN	Si	50		1.0	1.0	1.0	$h_{FE}:I_C - 12V, 1.0A$		TRA
XA151	5	PNPA	Ge	130	300	15	15	3.00†	$h_{FE}:I_C - 50ma$	20min	AEI
XA152	5	PNPA	Ge	130	300	15	15	5.50†	$h_{FE}:I_C - 50ma$	40min	AEI



# Market News . . .

## Sales

Revenue from factory sales of transistors last year rose more than \$109 million over the 1958 total and total units sold increased by more than 35 million, according to a year-end compilation by the Electronic Industries Association.

The following chart shows monthly and cumulative figures for unit sales and dollar value in 1959 and 1958:

1959	Units	Dollars
January	5,195,317	13,243,224
February	5,393,377	14,550,056
March	6,310,286	18,117,560
April	5,906,736	16,864,049
May	6,358,097	19,007,293
June	6,934,213	18,031,593
July	6,030,265	15,618,315
August	7,129,696	18,054,138
September	8,652,526	20,851,290
October	8,710,913	22,109,748
November	7,846,500	22,742,525
December	7,826,194	22,819,931

TOTALS 82,294,120 \$222,009,722

1958	Units	Dollars
January	2,955,247	6,704,383
February	3,106,708	6,806,562
March	2,976,843	6,795,427
April	2,856,234	7,025,547
May	2,999,198	7,250,824
June	3,558,094	8,262,343
July	2,631,894	6,598,762
August	4,226,616	9,975,935
September	5,076,443	10,810,412
October	5,594,856	13,461,857
November	5,440,981	12,441,759
December	5,627,700	16,595,616

TOTALS 47,050,814 \$112,729,427

The EIA also reports that this trend is continuing for over 1.7 million more transistors were sold during January than during the previous month and sales revenue was up more than \$1.8 million. The number of transistors sold during the first month of this year was nearly double the total for January a year ago while the dollar value of sales shows a gain of \$11.4 million.

The following EIA charts give totals for January of this year and December and January of 1959.

	Factory Sales	
	(Units)	(Dollars)
January 1960	9,606,630	\$24,714,580
December 1959	7,826,194	22,819,931
January 1959	5,195,317	13,243,224

Philco's Lansdale Division has moved its Phoenix, Arizona sales office to San Diego, California.

Knapic Electro-Physics today announced the opening of an eastern sales office in New York City. The new office is located in the Chrysler Building, on Lexington Avenue.

PSI Sales Department has moved to larger quarters in Hawthorne, California.

General Plate Products group of Texas Instruments Inc. has reported that its clad-metal volume in 1959 for the semiconductor industry was more than triple the preceding year's total. Sales in the

first two weeks of 1960 equalled the total for the year in 1957.

Transitron Electronic Corporation has established two new sales offices, located in Orlando, Fla. and Dallas, Texas. This brings to 19 the number of national sales offices.

## Expansion

Sylvania Electric Products, Inc. has just completed their facility in Towanda, Pa. The plant is expected to be in operation by early summer. It will offer production quantities of both monocrystalline and polycrystalline germanium and silicon.

Rheem Semiconductor Corp. has opened its new \$2 million, 100,000 square foot semiconductor plant in Mountain View, Cal.

Pacific Semiconductors, Inc., a producer of microminiature diodes, transistors and other semiconductor devices, has recently moved to larger quarters in Hawthorne, Calif. The new facility, a modern air-conditioned structure with 41,000 square feet of floor space, is larger than the entire original Culver City building in which PSI began operations in June, 1954.

Sperry Semiconductor's multimillion dollar expansion program got under way when ground was broken for their new headquarters, located on a 28-acre site in Norwalk, Conn. Completion of this new plant is scheduled for September, 1960. Future plans call for a 50,000 square foot addition to the 63,000 square foot plant now under construction.

A line of 412 different Germanium transistor types is now available from the newly-formed Electronic Transistors Corp., North Bergen, New Jersey. They are being manufactured under a patent license agreement with the Western Electric Company. The company will manufacture, in addition, a complete line of silicon transistors. All conform to applicable MIL specification. They will also produce power transistors in both semiconductor materials.

## Prices

Sylvania Electric Products, Inc., Semiconductor division is now offering its 2N388, an npn Ge alloy junction switching transistor in production quantities. These are priced at \$3.68 each in quantities of 1000 or more.

The firm is also offering a switching point contact diode, type D4121 for use in high speed military computers at \$4 each in quantities of 1000 to 9,999.

Transitron Electronic Corp. has added type 2N696 and 2N697 diffused mesa transistors to its line. Prices for the 2N696 in 1-99 quantities are \$21.75 each and for the 2N697, in the same quantity, \$22.70 each; in 100 and up quantities, the units are priced at \$14.50 each and \$15.15 each, respectively.

Pacific Semiconductor Inc., has available two diffused mesa transistors PT900 and PT901 which dissipate 125w. The

PT900 is priced at \$155 each and the PT901 at \$195 each in small quantities.

Trancoa Chemical Corporation, Reading, Mass., has announced the availability of polycrystalline silicon rods for floating zone crystal growing. The rods are offered in diameter from  $\frac{3}{8}$ " to 1". The nominal length of the rods is 10 inches with a boron content of approximately 1.0 ppb. The Trancoa price is \$1.00 per gram, a savings of approximately 20 per cent on this form of silicon.

Texas Instruments Incorporated has available for immediate delivery four different units of gallium arsenide tunnel diodes at prices ranging from \$9 to \$39 in quantity orders.

U. S. Semiconductor Products has announced two new Zener diodes of 10 and 50 watt units with standard tolerances of 5%. Fifty-three different types of 10 watt Zener diodes are available. A typical price is \$7.99 for the 1N1351A. In the 50 watt line a typical price is \$16.45 for the 1N2962A. The firm has also announced price reductions ranging from 15% to 45%, in approximately 75% of their devices. The major cuts were announced in the line of silicon reference elements in addition to the Zener diode line, a tantalum capacitors and other semiconductor devices.

Fairchild Semiconductor Corp., Mountain View, Cal. has introduced two general purpose silicon transistors which dissipate 1.5w at room temperatures. Type 2N717 is priced at \$22.70 and type 2N718 at \$24.05. Their new diffused Si transistor, type 2N698, is also priced at \$22.70 in quantities from 1 to 99.

Rheem Semiconductor Corp. has available a new line of fast switching, high current silicon mesa transistors. These have been numbered RT5001 through RT5004 and are available in quantity at \$38.70 to \$49.50 each. In addition the firm has announced prices on their Si glass diodes having a maximum recovery time of 4 mu sec. Types 1N903 through 908, 1N914 and 1N916 have an average price of \$4.25 each in quantities of over 100.

National Semiconductor Corp., Danbury, Conn., has reduced prices up to 28% on their silicon alloy transistors lines 2N1440 to 1442 and 2N327A to 329A.

Hughes Aircraft, Semiconductor division has cut transistor prices averaging 25% on p-n-p alloy junction types and averaging 20% on p-n-p silicon double diffused mesa types. Types 2N1228-1234 and 2N1238-1244 in the alloy junction line will average a reduction of 25%.

General Electric Co., Semiconductor Products department has sample quantities available of 22 ma and 10 ma peak current models of gallium arsenide tunnel diodes priced at \$55 and \$85 each.

The Lansdale Division of Philco Corporation announced an increased transistor quantity break enabling its industrial distributors to have transistors available in quantities 1 to 999 at factory prices.

## Distribution

Schweber Electronics, Mineola, L.I., N.Y. has been appointed a factory-price distributor for Daystrom Pacific Potentiometers and for Westinghouse Silicon Power Rectifiers and Transistors. Up to 1000 pieces of most rectifier and transistor types and up to 2000 pieces per potentiometer type can be obtained at factory prices.



# 300%

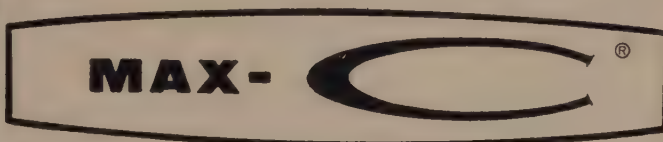
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Now you can cut precious inches and ounces from your assemblies with space-saving, weight-saving MAX-C Sealcaps.

The surprising increase in range of the Max C trimmer capacitor is obtained by embedding the electrode band in the glass cylinder. This design provides the thin dielectric required for a large capacitance range while retaining the ruggedness and mechanical strength of a heavy wall glass tube.

Included in the Max C design is the Sealcap construction which provides the additional stability safeguard of a completely sealed interior.

### MINIATURE PANEL MOUNT MAX-C SEALCAP SERIES

Model	Min.	Max. (PF)	Distance Beyond Panel	Maximum Diameter
MC601	1.0	14.0	29/64"	5/16"
MC603	1.0	28.0	11/16"	5/16"
MC604	1.0	42.0	29/32"	5/16"
MC606	1.0	60.0	1 5/32"	5/16"
MC609	1.0	90.0	1 3/4"	5/16"

The Max C retains all the advantages of glass tubular trimmers: Working voltage of 1000 VDC, Insulation Resistance of  $10^6$  megohms, Q of 500 at 1MC, operating temperature range of  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ , and high stability. It meets or exceeds the applicable performance and environmental requirements of Mil-C-14409A.

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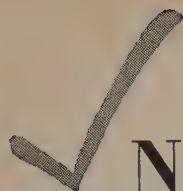
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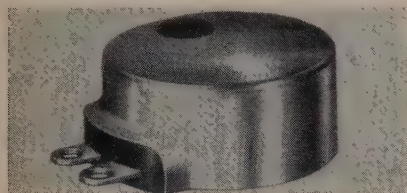
# New Products

## Solder And Flux Kit

A new solder and flux kit to help design and process engineers do experimental pre-production jobs that cannot be done with standard tin-lead solders is now available from Alpha Metals, Inc. Called the Alpha Solder and Flux R&D Kit, it consists of 16 varieties of soldering chemicals—fluxes, solder paste, flux and dross removers and printed circuit board coatings—11 kinds of flux-filled and solid wire solders in handy dispenser tubes, and 3 different foil solders for making preforms.

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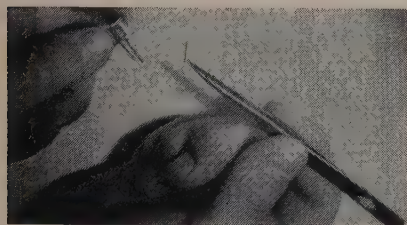
## Precision Thermostat



A low-differential precision thermostat that opens or closes on temperature rise has been announced by Spencer Products group of Texas Instruments Incorporated, Metals & Controls division. Designated KLIXON 4286, the device controls temperatures within 5°F maximum limits. For use as a control or warning device in guided missile, aircraft control, computer, crystal oven, etc. Continuous temperature exposure limits are -65°F to +270°F. Handles momentary overrides to +325°F on types designed to open on temperature rise, and overrides to +320°F on types that close on temperature rise. The temperature setting range is 0°F to +250°F.

Circle 154 on Reader Service Card

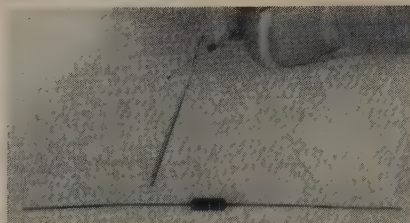
## Tweezers



New anti-magnetic "Eremit" Tweezers with high resistance to acids offer the electronic assembly industry important savings in time and tool stores, following development of a new tweezer base metal by Hunter Tools. During extensive tests on the assembly line of a Semiconductor manufacturer, the new Tweezers were used to remove "wafers" from acid baths to a neutralizing liquid. When dipped in a 50-50 solution of hydrofluoric and nitric acids for as long as ten minutes, the Tweezers retained their original appearance and operating characteristics.

Circle 151 on Reader Service Card

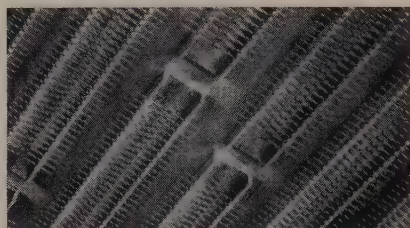
## Micro-Diode Series



A complete series of micro-diodes has been developed and placed into production by Transistron Electronic Corporation. They include: very fast diffused silicon micro-diodes, a series of high quality micro-regulators; a basic series of high voltage, high conductance micro-diodes; and a micro-stabistor. The basic family of multi-purpose micro-diodes, a series of three high quality diffused-silicon micro-diodes, provides voltage ratings up to 200 volts and the high forward conductance allows a current rating of 50 milliamperes; and can be used in switching applications.

Circle 156 on Reader Service Card

## Silicon Computer Diodes



Rheem Semiconductor Corp. ultra fast glass silicon diodes feature maximum recovery time of 4 millimicroseconds together with extremely low capacitance, typically less than 1 micro-micro farad. Listed under type numbers 1N903 through 1N908, plus 1N914 and 1N916, these units give voltage ratings up to 100 volts and average rectified current up to 75 mA. They are hermetically sealed in the standard subminiature glass package and are designed to exceed the requirements of MIL-S-19500B.

Circle 177 on Reader Service Card

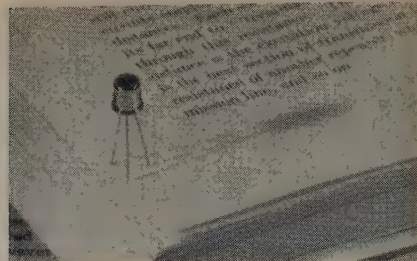
## Thermoelectric Modules



The use of a new bismuth telluride alloy in the production of thermoelectric modules now makes thermoelectricity an efficient as well as economical means of cooling volumes up to 4 cubic feet. Materials Electronic Products Corp. produces the *n*- and *p*-type alloy in the form of crystals up to 18 inches in length. Both crystal rods and thermoelectric modules made from the rods are available for experimental use or for production purposes. The *p*-type alloys have a figure of merit of  $4-4.5 \times 10^{-3}$ , and the *n*-type  $2.7-3 \times 10^{-3}$ , which, at 100°C, according to the company, gives Melcor's modules a temperature difference of 105°.

Circle 147 on Reader Service Card

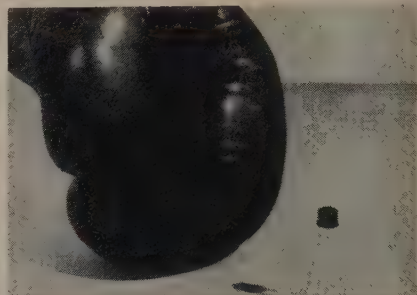
## Gallium Arsenide Tunnel Diodes



General Electric has announced the availability of gallium arsenide tunnel diodes in two models. They differ by peak current. The higher current unit has a typical peak current of 22-milliamperes while the other device is rated at 10-milliamperes peak current. Capacitance for both devices is typically 1.5 picofarads per milliampere. The typical peak to valley current ratio is 15 to 1. Typical voltage swing is 1.0-volt.

Circle 163 on Reader Service Card

## Switching Transistor



A high-speed switching transistor, 2N-1473 capable of surviving shocks in excess of 20,000 times the acceleration of gravity, has been developed by Sylvania. Designed for use in telemetered torpedoes, projectile fuzes, electronically guided high-impact missiles, and other applications where extreme acceleration shocks are encountered, the new transistor has maximum ratings of 40 volts  $V_{ce}$ , 20 volts  $V_{be}$ , 15 volts  $V_{eb}$ , 400 ma.  $I_c$ , -50°C to +75°C storage temperature, +75°C junction temperature.

Circle 161 on Reader Service Card

## Zone Refiner

Lindberg Engineering Company offers a Multiple Tube Horizontal Zone Refiner for germanium. From one to 12 quartz tubes can be mounted and used simultaneously, traversing a molten zone in each tube. A direct current drive powers a threaded shaft which is continuously variable from .8 to 16 inches an hour. Return speed is continuously variable from 40 to 800 inches an hour. Each tube will accommodate a 30" long carbon boat. Minimum vibration of the fixture allows single crystal growing in the horizontal position.

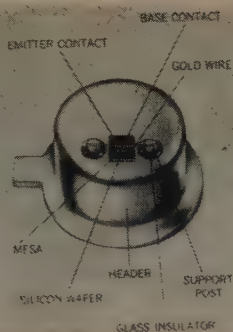
Circle 180 on Reader Service Card

## Planar Transistor

Fairchild Semiconductor Corporation introduces its new diffused planar structure silicon transistor, 2N1613. The new unit is different from mesa types in that both the collector to base and base to emitter junctions are embedded in the top surface of the planar structure. It has typically .0005 microamp ICBO at 60 volts, guaranteed useful beta over a range of collector currents from 100 microamps to one half ampere, a VCBO of 75 volts. Will dissipate 3 watts in JEDEC TO-5 package at 25°C case temperature.

Circle 172 on Reader Service Card





According to National Semiconductor Corporation, a new class of diffused silicon "mesa" transistors has been developed by them specifically to meet military and industrial requirements for production quantities of high quality, tightly controlled devices. Initially the new techniques are being used to produce two types of *n-p-n* transistors, the NS200, for switching applications in computer circuitry, and the 2N752 for high frequency amplification in video amplifiers, I.F. strips, telemetering and other applications. Output capacitance of both is 5 mmfd, leakage current at 150°C is 3 microamps for the NS200 and 5 microamps for the 2N752. Guaranteed minimum gain-bandwidth product for both is 200 megacycles. Collector saturation resistance of the NS200 is 35 ohms, 40 ohms for 2N752. Beta fall-off from 1 to 100 milliamps is less than 35% of peak value.

Circle 152 on Reader Service Card

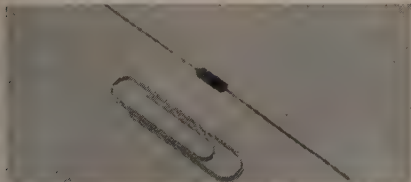
#### Hex Mount Zener Diodes



10-watt Zener diodes in standard 7/16" hex stud (DO-4) package are now offered with 5% standard tolerance by U. S. Semiconductor Products. Reverse breakdown voltages ( $E_z$ ) range from 7.5 volts to 100 volts, according to part number. The following series are available: 1N1351A-1N-1375A; 1N1806A-1N1808A; 1N1816A-1N-1836A; 1N2008A; 1N2498A-1N2500A. They provide excellent voltage regulation or reference, clipping, surge and under or over-voltage protection, meter protection, and may be used in many other unusual applications.

Circle 170 on Reader Service Card

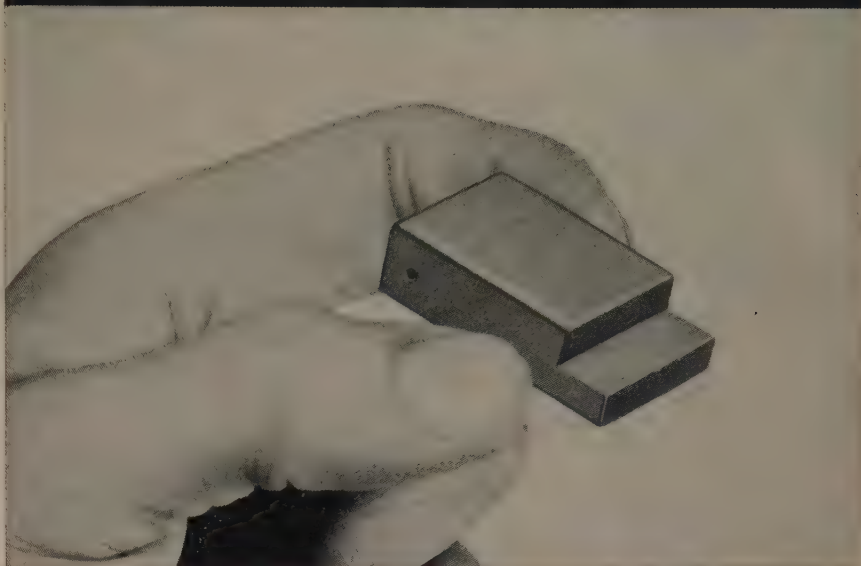
#### Diode/Rectifiers



Designed to operate at temperatures up to 200°C., new subminiature silicon diode/rectifiers in hermetically-sealed glass case (MP 100 through MP 600), have been developed by General Instrument Corporation and are now available in production quantities. Of fused junction construction, with pigtail leads, they are built to meet military specifications, cover the range from 100 to 600 volts peak inverse, and operate at ambient temperatures from -65°C. to +200°C. At 200°C. and 225 peak inverse voltage, maximum average rectified current is 50 mA.

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### Chops time from 20 hours to 30 minutes drilling and notching Silicon Carbide waveguide inserts

**PROBLEM:** Drill two .062"  $\pm$  .001 holes to a depth of .187  $\pm$  .002, and produce a notch .375  $\pm$  .001 wide x .250  $\pm$  .001 deep x 1" long with no internal radius allowed on the end of silicon carbide sticks. The pieces are for use as dummy loads in high frequency waveguides. Previously, the holes were cut with carbide drills and the notch produced with diamond wheels.

**SOLUTION:** A Raytheon Impact Grinding Analyst recommended drilling and notching with a Raytheon Impact Grinder using mild steel tools for both applications.

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**HOW YOU CAN BENEFIT:** Whatever your difficult cutting, slicing, drilling or shaping problem—in hard or brittle material, your Raytheon Impact Grinding Analyst can help you solve it. For full details, fill out the enclosed coupon and send it in. No cost or obligation.



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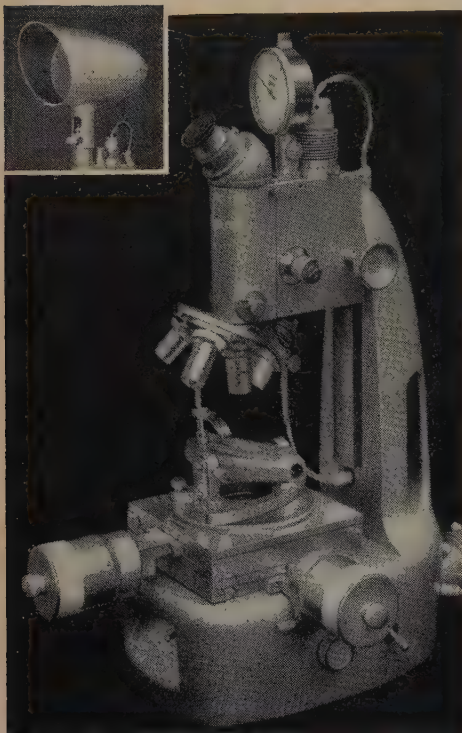
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# MEASURE TO 0.0001" IN 3 DIMENSIONS WITH UNITRON'S TOOLMAKERS MEASURING AND METALLURGICAL MICROSCOPE



The UNITRON Model TM is more than just a measuring microscope. It is the only instrument which combines in one stand a completely equipped toolmakers microscope for precise measurements — LENGTH, WIDTH and DEPTH, and a metallurgical microscope for examining the structure of polished metal samples under high magnification.

## NOTE THESE QUALITY OPTICAL & MECHANICAL FEATURES

- **Objectives:** achromatic, coated, 3X, M10X, M40X.
- **Eye-piece:** coated Ke10X with crosshair.
- **Magnifications:** 30X, 100X, 400X; up to 2000X with accessories.
- **Focusing:** Both dual control rack and pinion coarse and micrometer-screw type fine adjustments. Body has locking device.
- **Three Illuminators:** sub-stage, surface and vertical, have variable intensity.
- **Combination Stage:** rectangular ball bearing with linear measurements to 0.0001" and rotary measurements to 5' with vernier. (Metric model available on special order.)
- **Depth Indicator:** measures in units of 0.0001" by "optical contact" with specimen.
- **Projection Screen:** available as accessory for optical comparison.
- **Eye-piece Turret:** available as accessory for measuring surfaces, radii, thread pitch etc.

In fitted hardwood cabinet

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Circle No. 34 on Reader Service Card

### Wire Bonder

Kulicke and Soffa Mfg. Co. Model 400 Transistor Wire Bonder is used to bond the contact wires between the semiconductor material and the header terminal post in transistor manufacturing. The basic instrument can also be adapted to other micro-assembly techniques. The instrument features an optional continuous wire feed. (The standard model has a Wollaston wire feed.) Other features include a single-control, chessman-type micropositioning mechanism for X-Y axes adjustments.

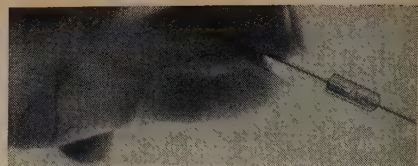
Circle 169 on Reader Service Card

### Gas/Air Recirculator

C. I. Hayes, Inc. recirculating Molecular Dryer Type MS-R is a simple, compactly designed gas and air dryer complete with an atmosphere recirculating unit. This new adsorptive unit has been designed specifically around Linde Company's 5A Molecular Sieve material. Type MS-R incorporated into a closed-cycle system, now permits substitution of pure dry air, with dew points to -100°F or lower, for tank nitrogen ordinarily used for "dry box" assembly of transistors, diodes and other electronic parts.

Circle 159 on Reader Service Card

### Tunnel Diodes



Sperry Semiconductor has announced the immediate availability of germanium tunnel diodes covering a wide range of typical peak currents. Sample quantities of types T101-T105, with peak currents ranging from 0.8 ma to 20.0 ma are available. Peak to valley current ratios on all types are in excess of 5.0 to 1, typically 8.0 to 1. They have a typical peak point voltage of 50 millivolts and typical valley point voltage of 250 millivolts. Operating and storage temperature range is from -55 to +100°C. The units have a 100 milliwatt dissipation rating at 25°C.

Circle 175 on Reader Service Card

### Micro-Transistor Series

Specifications on a new series of Micro-Transistors were released by Pacific Semiconductors, Inc. One series is approximately 1/50th the size of the standard TO-5 package. An alternate type, available for experimental use is in ultra-micro-miniature form, and is 1/200th the size of the TO-5 package. The new Micro-Transistor is a triple-diffused n-p-n silicon mesa device designed as a low-power high speed switch.

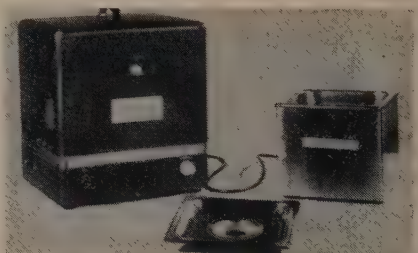
Circle 164 on Reader Service Card

### New Power Supply

Victory Electronics, Inc. announces the "Victory Variant", a power supply on which you can change regulation without any change of wiring or removing supply from its mounted position. The regulator can be easily removed and operated separately and the power unit can be operated as a 1% regulated power supply. When they are reunited, they form a highly regulated power supply.

Circle 166 on Reader Service Card

### Ultrasonic Cleaner



A new addition to the McKenna Laboratories "Poly-Sonic" series ultrasonic cleaners, which feature several simultaneous ultrasonic frequencies, the V-100 provides especially thorough cleaning because it produces uniform concentration of ultrasonic power throughout the cleaning chamber. Completely uniform cleaning results are obtained throughout the volume of the container even in a parts basket. Another feature of the "Poly-Sonic" units is the more effective cleaning through the use of heated solutions.

Circle 196 on Reader Service Card

### Silicon Junction Rectifier

Trans-Sil Corp. Type MR series of double-diffused junction silicon rectifiers will deliver up to 3.0 amperes, half wave, with proper heat sink, in ambients up to 150°C. In full wave circuits, currents up to 9.0 amperes can be realized. They are hermetically sealed cells particularly suited for power supply and magnetic amplifier applications.

Circle 179 on Reader Service Card



## Soft Solder Alloy Preforms



Using ultra-pure vacuum casting techniques, Accurate Specialties Co., Inc., is now offering industry a complete range of soft solder preforms with alloying elements of lead and tin held to 99.999 + % purity. Melting points range from 361°F to 689°F. Preforms are available in the form of flat washers, discs and pellets. In order to assure continued purity, the parts are packaged in argon or other protective atmospheres prior to shipment thus assuring indefinite shelf life.

Circle 158 on Reader Service Card

## Solid State Current Limiter

Microelectron Current Limiters are made entirely of electrically conductive ceramic raw materials, which are deposited as thin film constructions on glass or aluminum oxide substrates. The device is a junction which is highly sensitive to overload currents. Consequently it can be used to protect other components which may be seriously affected by overload. It can be used to protect transistors, rectifiers, diodes, galvanometer movements and the like. It is particularly useful in protecting semiconductor junctions, since its response time is faster than the time-current required to damage a typical junction.

Circle 149 on Reader Service Card

## Gas Diffusion Furnaces

A major breakthrough for gas diffusion in the semiconductor industry, the new DZ series Furnaces are announced by BTU Engineering Corporation for continuous alloying, fusing, bonding, brazing, soldering and metal-to-glass sealing under controlled atmospheres. Features include: a true temperature flat to specified tolerances, stepless temperature control with controlled rectifiers, a tiltable furnace for best results in open end or closed tube diffusion, optimum insulation for stability, provisions to increase the number of controls for specific results.

Circle 157 on Reader Service Card

## Switching Transistor



A new high speed, high current silicon switching transistor, designated 2N1072, is now available for military application from the Radio Division of the Western Electric Company. The unit is a double diffused *n-p-n* mesa type transistor, capable of switching currents up to 1 ampere with rise and fall times of 50 millimicroseconds. At 750 milliamperes of collector current, this transistor has a saturation voltage between 0.7 minimum and 2.0 maximum, its *hFE* is 15 minimum, and the base input voltage is 0.7 volt minimum and 1.8 volts maximum.

Circle 173 on Reader Service Card



# f<sub>T</sub> Instantaneously!

## Transistor Frequency (f<sub>T</sub>) Response Meter Model F-20

### SPECIFICATIONS:

- Frequency Range (f<sub>T</sub>)
- Accuracy
- Power Consumption  
(exclusive of transistor under test)
- Self contained collector  
bias voltage for transistor under test
- Self contained emitter  
bias current for transistor under test
- Size

50-750 mc/sec  
± 5%  
Less Than 250  
Milliwatts  
0-15 volts in  
1.5v steps  
0-10 ma in  
1 ma steps  
14" W x 9" D x 9" H

### FEATURES:

- Direct reading, f<sub>T</sub>, in mc/sec
- *hFE* by simple calculation
- Polarity PNP, NPN
- Simple, direct, and precise instrument calibration
- Provision for external biasing of transistor under test beyond V<sub>CB</sub> = 15 v, I<sub>E</sub> = 10 ma
- Provision for automatic recording
- Transistorized; Long Life
- Self contained; battery powered, ready for immediate operation

### APPLICATIONS:

- Tests all transistors, silicon or germanium, within frequency range
- Suitable for laboratory testing and evaluation
- Suitable for production testing
- A tool for transistor design
- Suitable for determining frequency response variation with bias voltage and current
- Rapid Testing

**Molecular Electronics INC**

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Temperature Control**

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infinitely modulate electric heat.  
No on-off pulses. Prolongs heater-life,  
saves power. Exclusive manual  
switch, adjustable maximum and  
minimum input control. *Tubeless*.  
Compact. Least maintenance and  
operating attention required.



#### **PROGRAMMER (Model JSBG Stepless)**

for the most *precise* control of temperature-  
time cycle, integrated by simply cut  
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secondary operation at any point in the  
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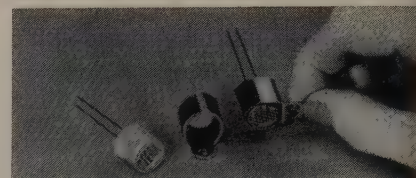
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#### **Solder Paste Alloys**

The solder paste alloys developed by Physical Research Laboratories are highly specialized solder media which utilize special atomized eutectic alloys and precision controlled flux chemicals especially suited for soldering nickel chrome resistance alloys, stainless steel, and numerous other complex alloys known to those in the electrical and electronics fields. PRN 390 has a melting point of 225 degrees C. and contains a special proprietary flux that is capable of sufficient activity, yet leaves no corrosive residue. LS-59 has a melting point of 585 degrees F. and provides greater bond strengths. PRN-400 is a solder paste alloy with a melting point of 439 degrees F.

Circle 160 on Reader Service Card

#### **Photoconductive Cells**



One-half inch diameter power cells of the photoconductive type, combining relatively high dissipation ratings with a small, hermetically sealed package, have been announced as available in a new series, the 500 Line, by Clairex Corporation. Type 504 is an extremely sensitive Cadmium Selenide type with a relatively high speed of response; the 505, Cadmium Sulphide.

Circle 187 on Reader Service Card

#### **Transistor Tester**

A transistor test and classification computer is being manufactured by Industro Transistor Corporation. The instrument, ITVAC (Industro Transistor Value Automatic Computer), is available in several models, and can test 750 transistors per hour, classify them according to programmed specifications and record the test data of each unit in one or more of several recording methods. Accuracy of the machine is on the order of  $\frac{1}{4}$  of 1%, and is maintained by a series of self-checks that ITVAC undergoes before every transistor test. A battery of standard cells built into the machine is used as a reference by the machine before testing.

Circle 165 on Reader Service Card

#### **Silicon Transistor Series**

Western Transistor Corporation revealed development and production of a new series of *p-n-p* silicon alloy transistors, carrying the trade name "WesTran". The '327' series is designed for switching and general purpose application at low and medium power levels. Engineered to exceed Mil Spec T-19500, they are more structurally rigid than required in such environmental conditions as acceleration, shock, strong impact, and thermal fatigue.

Circle 192 on Reader Service Card

#### **Component Life-Test Oven**

A new elevated-temperature thermostatically controlled life-test oven with complete internal power-supply and test-facility circuitry has been introduced by ITT. The new unit handles 660 bi-polar components or 330 tri-polar devices. Standard units are rated at 125°C maximum. Test circuitry is rated at 750 volts and 5 amperes with resistance less than 0.5 ohm. Power requirements are 1600 watts at 115 or 230 volts and 50 or 60 cycles.

Circle 193 on Reader Service Card

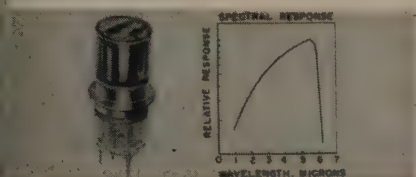


### Solid Circuit Networks

Texas Instruments Incorporated has announced the availability of its Solid Circuit semiconductor networks. Each network is a complete functioning electronic circuit fabricated within a single piece of high-purity semiconductor crystal the size of a matchhead. The new networks offer promise of greatly improved reliability in addition to dramatic size reduction. Wide application is anticipated in missile and airborne electronics where miniaturization and reliability are of prime importance. Applications already are being made in the computer field.

Circle 155 on Reader Service Card

### Infrared Detector



A new infrared detector of extremely small area ( $0.1 \times 0.1 \text{ mm}^2$ ) is now being produced by Radiation Electronics Company. Utilizing the photovoltaic effect in indium antimonide at liquid nitrogen, the Model J-02 detector exhibits typical NEP values of  $2 \times 10^{-12}$  watt at 5 microns and  $4 \times 10^{-12}$  watt for  $500^\circ\text{K}$  Blackbody. It responds from the visible region to 5.7 microns with a time constant of less than one microsecond.

Circle 186 on Reader Service Card

### Insulator Wafers

Hard-anodized insulator wafers for stud mounted diodes have been added to Monadnock Mills line of insulator wafers for semiconductors. Wafers provide outstanding dielectric insulation and thermal conductivity. Installed between diode and chassis and between hex jam nut and chassis. Extruded center hole insulates stud from chassis and eliminates necessity for separate insulating bushing.

Circle 194 on Reader Service Card

### Diode Testing System

For manufacturers and users of diodes, the Flite-Tronics TM-1 Visual Diode Evaluation Monitor combined with the Model DE-48 Module simulates aging and provides rapid, efficient dynamic testing of diodes in quantity. Forward conduction current and reverse voltage of the diodes under test are readily monitored, when the output of the TM-1 is connected to a dual trace oscilloscope.

Circle 195 on Reader Service Card

### Transistor Test Set

The Dynatran Model 1802 RF Transistor Test Set is designed to measure the important RF parameters of both  $n-p-n$  and  $p-n-p$  transistors. This set provides direct readings of the alpha cut-off frequency and gain bandwidth product for junction transistors up to 50 megacycles. It also provides direct readings of the  $r_b C_c$  product and the collector output capacity. This instrument is complete in itself and requires no auxiliary equipment. It is power line operated and contains no batteries.

Circle 150 on Reader Service Card

### Silicon Power Transistors

A new group of 12 diffused-junction power transistors of the silicon  $n-p-n$  type was announced by RCA. They are intended for a wide variety of applications in industrial and military equipment operating at temperatures ranging from  $-65^\circ\text{C}$  to  $+175^\circ$ .

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*aimed toward  
more efficient  
performance of  
electronic components*


**LABLINE**

# PRODUC-TEMP BATH



**Newly developed  
for testing  
SEMICONDUCTOR COMPONENTS**

The new Produc-Temp Bath answers today's need for more critical equipment to test component reliability. Ten separate thermistor controls in the Produc-Temp Bath maintain variable temperatures within  $\pm 0.1^\circ\text{C}$ . Bath temperatures can be kept constant or varied from  $100^\circ\text{C}$  to  $-55^\circ\text{C}$ . While fluid is agitated, test materials can be immersed and rotated in all possible planes. Mail coupon today.

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JUNCTION  
THERMAL  
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REPRODUCIBLY**

**TEST  
CONTROLLED  
RECTIFIERS  
DYNAMICALLY**

**GENERATE  
ONE 5000 AMP.  
SINUSOIDAL  
PULSE**

**EVALUATE  
A 500 AMP.  
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AT 1500 VOLTS**

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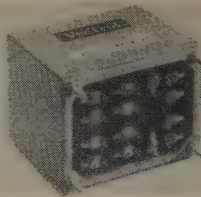
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Circle No. 38 on Reader Service Card

#### Silicon Power Rectifiers



A full range phase shift control for Silicon Controlled Rectifiers of all makes and ratings has been announced by Vectrol Engineering, Inc., under the registered trademark "SILICONTROL." A supersensitive phase shifting network applies 60 cycle steep pulses of constant amplitude to rectifier gates and varies their phase angle over 180° to control the rectifier output from zero to maximum. Pulse rise time is only a few microseconds.

Circle 185 on Reader Service Card

#### Semi-Automatic Tester

Monitor Systems, Inc. announces the development of a component checkout system, the SATT (Semi-Automatic Transistor Tester). The rate of transistor testing is in the order of 30 or 60 tests/second, within an accuracy of 0.5%. Though primarily intended for the transistor industry, is easily modified to test many other types of electronic components (resistors, capacitors, diodes, tubes, etc.) printed cards, and subassemblies.

Circle 182 on Reader Service Card

#### Tunnel Diode Curve Tracer

The new Trak Electronics Tunnel Diode Curve Tracer is an instrument for use with a laboratory oscilloscope and presents the current-voltage characteristic of tunnel diodes throughout the negative resistance region. The available range exceeds that necessary for testing currently available tunnel diodes in anticipation of new diodes with different characteristics. The accuracy of conversion from current to voltage is  $\pm 1\%$ .

Circle 183 on Reader Service Card

#### Ultrasonic Cleaner

A new Circosonic cleaner that combines the advantages of high frequency ultrasonic cleaning, plus mechanical agitation action in a single unit, has been developed by the Circo Ultrasonic Corporation. In the new unit, the ultrasonic sound waves loosen the foreign matter from crevices, blind holes and threads, leaving the agitation action to float it away. Generator (PG500) and transducers (two model 4090B's) have an output of 500 watts av., 1,000 watts peak; frequency of 40 KC.; power output of 1,500 watts, 115 volts, 60 cycles, 1 ph., weight of 75 pounds. Overall dimensions of the units are 19" wide x 14" high x 15" deep.

Circle 191 on Reader Service Card

#### Dry Box Gloves

"Rad-Bar" lead-loaded dry box gloves, made by an exclusive formulation of Charleston Rubber Company now are being offered in standard heavyweight and lightweight thicknesses, in several dimensions, styles and hand sizes. These lead-loaded Neoprene gloves are of a density of 3.95 grams per cubic centimeter. Tests conducted on Cadmium 109 at .087 Mev. show that the heavyweight glove, with 0.060" nominal overall glove thickness has a lead equivalent of 0.36 MM and the lightweight glove with 0.030" nominal overall glove thickness has a lead equivalent of 0.10 MM.

Circle 153 on Reader Service Card

**it's all in  
knowing  
how**

## HIGHER YIELD OF DEVICES

*with*

**LOW DISLOCATION DENSITY  
SILICON AND GERMANIUM  
SINGLE CRYSTALS**

*without*

**CROW TRACK  
or  
GROSS SLIPPAGE**

Rapid uncontrolled cooling of crystals during growth induces severe stress, which often causes these two common defects. The best 'preventive medicine' is the experience and knowledge of the grower — the "knowing how".



Test for 'crow track' by etching thin slices with a rapid etch. Then examine for cracking of material. The crack formation will differ with orientation, 111 orientation shown here.

Gross slippage can be detected by a dislocation etch pit count. Here, the slippage (120°) 'star' pattern of 111 oriented material is shown. 100 oriented material will display a 90° 'cross' pattern.



Our "growing" reputation, for quality of product grown to absolute specifications, is based on our clients' experience and knowledge — of us. Perhaps we can help you as well.



SEMICONDUCTOR MATERIALS

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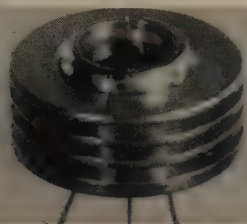


### Full-Effect Device

The latest in a series of new Halltron full-effect devices has been introduced by Ohio Semiconductors, Inc. An axial lead probe known as the Model HP-315, utilizes indium arsenide (InAs) for the active element. It is capable of application from  $-35^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  and has a temperature coefficient of approximately  $-0.1\%$  per degree C. With a control current of 100 milliamperes and a flux density of 10 kilogauss, the nominal open circuit full output voltage is 100 millivolts.

Circle 181 on Reader Service Card

### Heat Sinks



The availability of two new heat sinks for JEDEC-30 transistors was announced by the Thermolloy Company. The #2208 and #2209 are general purpose heat sinks for TO-5 and TO-9 outline transistors. Designed especially for Mesa transistors, these heat sinks can be used both for printed circuit board applications and mounting directly to metal chassis.

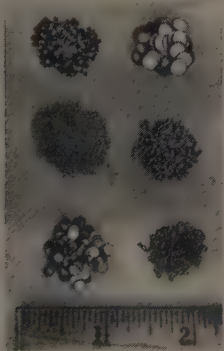
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### Alumina Abrasives

Geoscience Instruments Corp. announces abrasive crystals which meet the critical requirements of the electronic and semiconductor industry and which will produce the ultra high polished surfaces necessary for advanced device fabrication. "Corunda" (Liquid Sapphire & Liquid Ruby) is produced under the most exacting conditions assuring a new standard of uniform particle size. Homogeneity is certified by the laboratory analysis of each batch produced. Every run is graded and the particle and size and lot number recorded on the containers.

Circle 167 on Reader Service Card

### Semiconductor Preforms



Lead-antimony preforms for  $n-p-n$  type transistors are now available from Alpha Metals, Inc. The alloy combination most commonly used consists of 90% lead, 10% antimony, and has a melting point of  $252^{\circ}\text{C}$ . Other alloy combinations, too, are available. The purity of the metals used exceeds 99.999%. They are available as spheres, discs, cylinders, cubes, and are also preformed into drops, washers, rings and special shapes. Alpha fabricates this alloy as cylinders with a diameter of .008" and a thickness of .010" in production quantities.

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# NEW

# ZENER VOLTAGE TESTER\*



### APPLICATIONS:

- Laboratory Experimentation
- Circuit Design
- Quality Control
- Trouble Shooting
- Production Testing

Provides Automatic Presentation Of:

zener diode voltage . . . transistor breakdown and zener voltage . . . diode inverse and reverse voltages. Also Tests For . . . zener diode impedance.

ERA's new Zener Diode Tester, Model DT100 is a self contained AC operated instrument designed for direct reading of zener voltage as a function of diode current. Provisions are also included for AC modulation of the diode current to permit the determination of zener impedance or zener slope for any given value of diode current. The instrument incorporates a wide range adjustable constant current generator which injects the desired value of current into the diode under test and maintains this current constant independent of line voltage fluctuations or zener voltage and impedance. The voltage appearing across the non-linear diode impedance is read directly by a high impedance DC voltmeter for the given current setting.

### SPECIFICATIONS

Input Source . . . . . 115VAC, 60cps  
Zener Voltage Range . . . . . 0-300VDC  
Zener Current Range . . . . . 50 Microamperes-50ma  
Measurement Accuracy . . . . . Better Than 2%  
Metering . . . . . Direct Reading Ez, Iz  
Zener Impedance . . . . . Provision for AC Modulation Iac, Eac Reading  
Physical . . . . . Sloping Front Cabinet, Size:  $12\frac{5}{16} \times 8\frac{3}{4} \times 9\frac{1}{16}$  inches

Model DT100 \$275.00 \*

\* FOB Factory, Subject to change without notice

ERA manufactures a full line of transistor test equipment and transistorized devices. Write for complete technical bulletin on this (Catalogue #115) and related devices.

\*Pat. Appl. For

## ELECTRONIC RESEARCH ASSOCIATES

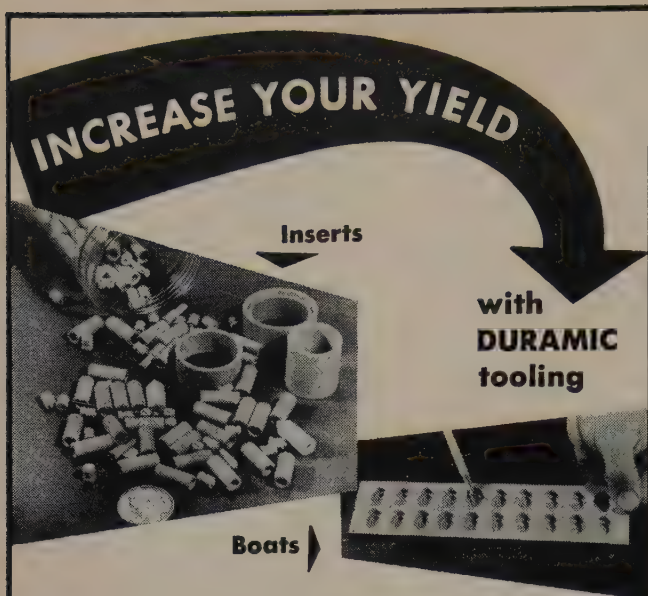
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## Industry News

### CONFERENCE CALENDAR

The Following June 1960 Meetings Are Scheduled:

- June 12-15 American Nuclear Society meeting, Chicago.
- June 15-18 American Physical Society, McGill University, Montreal, Canada. Sponsored by AIP.
- June 20-24 AIEEE Summer General Meeting, Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.
- June 22-24 Electronic Standards & Measurements Conference, National Bureau of Standards Boulder Labs, Boulder, Colorado. Sponsored by PGI, NBS, AIEEE. For Information: George E. Schafer, National Bureau of Standards, Boulder, Colo.
- June 23-24 Workshop on Solid-State Electronics, Purdue University, West Lafayette, Indiana. Sponsored by PGE, ASEE. For Information: Dr. James Mulligan, New York University, University Heights, Bronx, N. Y.
- June 26-July 1 American Society for Testing Materials Annual Meeting, Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.
- June 27-29 National Convention on Military Electronics, Sheraton Park Hotel, Washington, D. C. Sponsored by PGMIL. For Information: Dr. Craig Crenshaw, Dept. of Army, SIGRD-2, Washington 25, D. C.

Dr. Farrington Daniels, vice president of the National Academy of Sciences and professor emeritus of the University of Wisconsin, will present the annual Edgar Marburg Lecture at the 63rd Annual Meeting of the American Society for Testing Materials, in Atlantic City, June 29. This annual lecture is a memorial to the first secretary of ASTM and was established to emphasize the importance of furthering the knowledge of properties and testing of engineering materials. The launching of the artificial planet, Pioneer V, to orbit around the sun focuses attention dramatically on the use of solar energy to power the radio transmitters which are sending scientific data back to earth. Dr. Daniels will discuss the abundance and limitations of solar energy and will review solar energy research, emphasizing particularly the new materials which are necessary in the successful application of solar energy. The research review will include the subjects of heating, cooling, distillation of salt water, solar engines, photoelectricity, thermal electricity and photochemistry. New materials to be discussed will include: plastics for reflectors and covers for solar collectors; silicon in solar cells; solid state devices for thermoelectric and thermionic energy converters; refrigerant systems for possible appli-

(Continued on page 74)



**GILLINGS-BRONWILL**

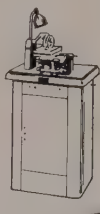
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AND  
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CRYSTAL SECTIONING .005" to .010"

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Other high purity TADANAC Brand metals or compounds include Special Research Grade antimony, indium and tin; High Purity Grade bismuth, cadmium, indium, silver, tin, zinc and indium antimonide. Send for our brochure—TADANAC Brand High Purity Metals.

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# PHYSICIST

## ADVANCE DEVELOPMENT OF SEMICONDUCTOR DEVICES

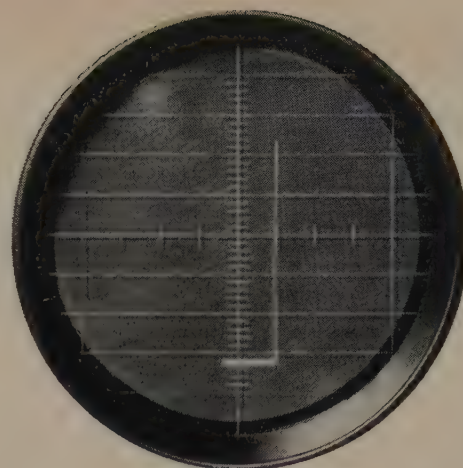
PHD, MS or equivalent with a background in solid state physics or electronics to analyze the operation of high frequency devices leading to the development of new device structures.

WRITE: M. D. Chilcote, Div. SP-5

Electronics Park, Syracuse, New York  
Semiconductor Products Dept.

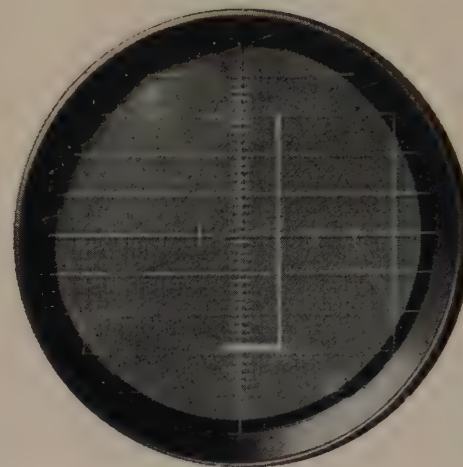
# GENERAL ELECTRIC

SEMICONDUCTOR PRODUCTS • MAY 1960



(before)

Reverse leakage tracing before immersion in  $H_2O_2$ .



(after)

Reverse leakage tracing after immersion in  $H_2O_2$ , dried without washing (virtually no change).

## Here's proof !

No increase in reverse leakage when you etch diodes in

## BECCO Hydrogen Peroxide!

To test the effect of impurity-free Becco Hydrogen Peroxide across an unsealed diffused silicon junction diode, the following "torture test" was performed: 600 volts AC were applied across the diode, and the reverse leakage current depicted on an oscillograph. Then, the diode was immersed in Becco 30% Reagent Grade Hydrogen Peroxide. The diode, without being washed in any way, was placed on a hot plate and the  $H_2O_2$  was evaporated.

The voltage was re-applied and the tracing produced was virtually identical (see above)—proof that no impurities that could affect the diode exist in Becco Hydrogen Peroxide.

Of course, you'll use Becco  $H_2O_2$  at a different stage—when you etch the diode. And, of course, good practice still dictates that you wash the diode in pure water following the etch. Nevertheless, this test proves that you need not be too concerned with your wash when you etch in Becco  $H_2O_2$ , since the peroxide itself, made by an inorganic method, can not deposit any impurities of its own on the diode.

Becco packages its Reagent Grade  $H_2O_2$  in returnable or non-returnable polyethylene containers to insure its purity when it arrives at your plant. Write us for further information or specifications, analysis, prices, etc. Address: Dept. SP-6.



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REH-4-30	800 W.	15	0.26	1-9/16"	7-7/8"	\$32.94
REH-4-60	1200 W.	29	0.65	1-9/16"	19-3/4"	\$54.32
REH-7-30	1200 W.	24	0.44	2-3/4"	7-7/8"	\$38.21
REH-7-60	1800 W.	46	1.05	2-3/4"	19-3/4"	\$73.47
REH-10-30	1800 W.	34	0.59	4"	7-7/8"	\$39.61
REH-10-60	2500 W.	63	1.44	4"	19-3/4"	\$76.48

\* Std. units can be arranged in series to provide a variety of heating lengths.

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# METALLURGIST

## ADVANCE DEVELOPMENT OF SEMICONDUCTOR DEVICES

PHD or MS or equivalent with background in Physical Metallurgy or solid state to assist in development of micro metallurgical techniques under protective atmospheres, vacuum deposition of high purity metals, and the study of re-crystallization of rare metals during alloying and welding operations on subminiature scale.

WRITE: M. D. Chilcote, Div. SP-5

Semiconductor Products Dept.

Electronics Park, Syracuse, New York

**GENERAL  ELECTRIC**

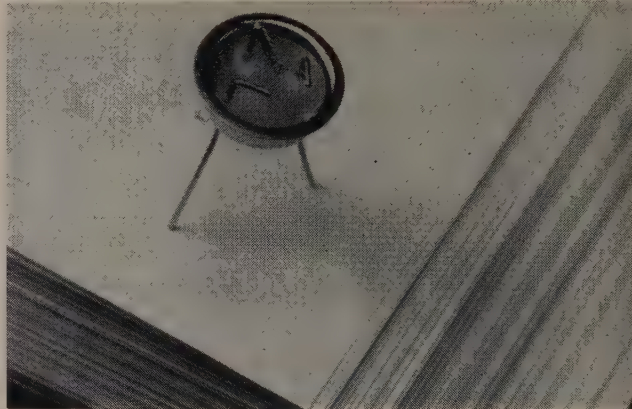
## Industry News

(from page 72)

cation in solar cooling cycles; and selective coatings for attaining high efficiency energy absorbers.

## RESEARCH & DEVELOPMENT

A new concept in transistor design involving high speed switching at low power levels for computer usage has been achieved by the Lansdale Division of Philco. Called a "micro-energy" switch, this device has been designed and constructed so that all internal device capacities are exceedingly small. Philco's first micro-energy switch features an emitter transition capacity less than one-third and a collector capacity approximately one-half that of conventional units. The gain bandwidth product is specified to be greater than 125 mc at a collector voltage of 1 V and a collector current of 1 ma and the beta characteristic optimizes at approximately 1 ma. The minimum saturation current gain of the transistor is 25 at a collector current of 2 ma. This switch will operate in simple high-speed logic circuits at pulse rates in excess of 10 mc when switching collector currents as small as 1 ma from collector supply voltages as small as 1 V. It permits the design of high-speed logic circuits operating with an overall power consumption of less than one-third that of circuits designed with conventional transistors. Micro-energy switches now being designed will widen this gap considerably.



The development and commercial availability of a man-made diamond for metal bonded grinding wheels has been announced by the Metallurgical Products Department of General Electric Company. Typical particles of the new diamond are of single crystal and blocky shape, with many showing regular crystal faces. The color ranges from light green to gray-black with light colored particles predominating. Crystal surfaces are smoother than the resinoid-vitrified bonded type, but are still considerably more irregular than the surface of natural diamond fragments of similar size, according to the company. They are available in sizes up to 100 mesh, and will be used in metal bonded grinding wheels for lens laps, glass grinding, (including pencil edging and beveling) electrolytic grinding and conventional grinding on cemented carbide. Other applications favored are forming and shaping of synthetic sapphires, cutting germanium and quartz, and the grinding of ceramics for missile components, such as ceramic nose cones.

Under the sponsorship of a Signal Corps research and development contract and also a separate fabrication contract, an X-band solid-state maser amplifier, the "ruby maser," was developed and fabricated by Hughes Aircraft Company. The effort under the contract was directed toward obtaining the maximum gain-bandwidth product and toward making the amplifier as stable and compact as possible. Achievement of substantial miniaturization in

(Continued on page 76)





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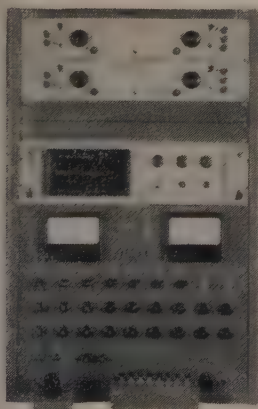
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## SEMI-CONDUCTOR TEST EQUIPMENT



### COMPUTER TEST SET

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- MANUAL
- SEMI-AUTOMATIC
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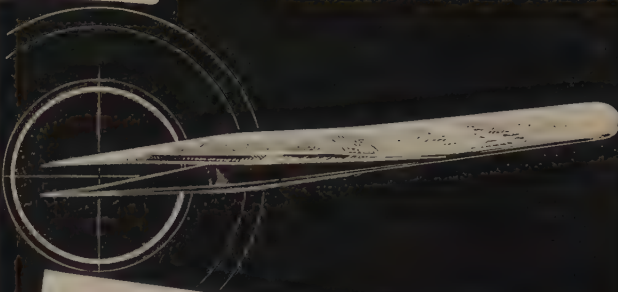
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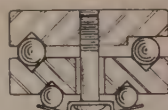
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HUNTER TOOLS — SEMI CONDUCTOR TWEezer DEPT. SANTA FE SPRINGS, CALIF.



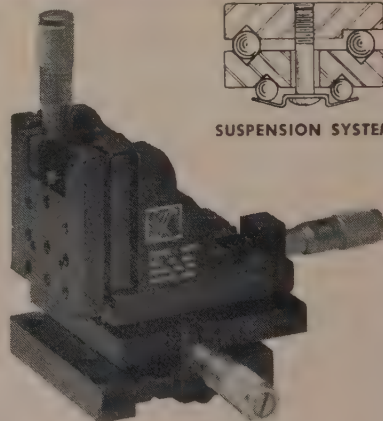
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### Industry News

(from page 74)

maser design is reflected in the over-all weight and size which are 25 pounds and  $\frac{1}{8}$  cubic foot respectively. The gain-bandwidth product of this amplifier is 105 Mc when operating at the temperature of liquid helium (4.2° K). The paramagnetic crystal employed in the amplifier is synthetic ruby having about 0.1% chromium concentration. Basically, high performance, reliability and miniaturization all are achieved by the use of a "ruby cavity."

An analysis of the efficiency of solar batteries such as those mounted on the paddles that power the paddle wheel satellite was presented at the American Physical Society meeting in Detroit recently by Drs. Hans J. Queisser and William Shockley. In commenting on his investigation carried out under contract with the Air Force Wright Air Development Center, Dr. Shockley said "The investigation leads to the important conclusion that no known basic reason precludes an improvement of 50% in solar batteries by better fabrication methods. The relative inefficiency of present solar batteries arises from unknown and uncontrolled recombination centers which absorb unnecessarily large fractions of the electric current generated by sunlight. Research on the nature and elimination of these unwanted centers will pay big dividends in the program of sun-powered batteries."

General Electric Company announced that it has developed a transistorized multiplex-carrier system capable of handling up to 600 voice frequency channels on a single radio beam. Fully transistorized, the new single sideband suppressed carrier system has toll quality capable of meeting international and domestic long-distance standards, according to the company. It will be of primary importance to telephone and wire line companies but also will have substantial benefits for utilities, railroads, pipelines and other users of microwave and cable systems.

Bendix Radio Division's 2R series transistorized railroad radio provides end-to-end, train-to-train, and wayside-to-train communications. Its advantages include greater receiver sensitivity, 12-watt audio output, and facilities for up to four-channel operation, according to the company. Other features include completely transistorized power supplies for the 12- and 72-volt units, transistorized receiver, transistorized audio circuit in the transmitter, a transistorized "protective" circuit in the 72-volt unit to guard against overloads, an optional "battery saver" circuit for the 12-volt unit to reduce drain when the unit is in stand-by (receiving only) condition.

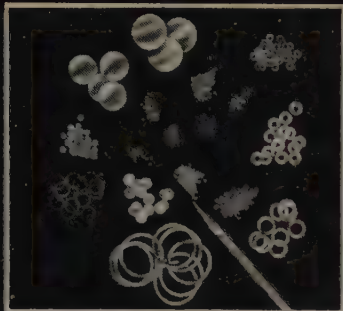
Minnesota Mining & Manufacturing Co. officials stated recently that a thermoelectric generator research and development contract just awarded 3M by the Navy Department represents an important step in the development of practical applications for thermoelectric materials and devices. The 3M Company was one of two firms awarded research and development contracts for a 500 watt gasoline or gas fueled thermoelectric field generator. The portable generator, which is designed to power surveillance radar, communications equipment and other field gear, must weigh no more than 35 pounds.

Robert W. Fritts, manager of 3M's thermoelectricity program, said, "We feel the major markets, both military and commercial, for thermoelectric generators in the years immediately ahead will involve gas and gasoline burning devices producing 1000 watts of power or less. We have been working for some time on the design and construction of a device very similar to that which the Navy has specified and our thermoelectric group has many years of experience in working with modified lead telluride, which is considered one of the best materials available for generator applications such as this."



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  - Binary Systems
  - Ternary Systems
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  - Phase Diagrams
- Low Melting Solders
- Bearing and Brazing Alloys
- Metallography of Alloys
- INDALLOY Intermediate Solders
- Nomographic Charts of Pellets and Spheres
- Chemical Properties and Compounds of Indium
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  - Electrochemical Methods of Analysis
  - Physical Constants of Inorganic Compounds
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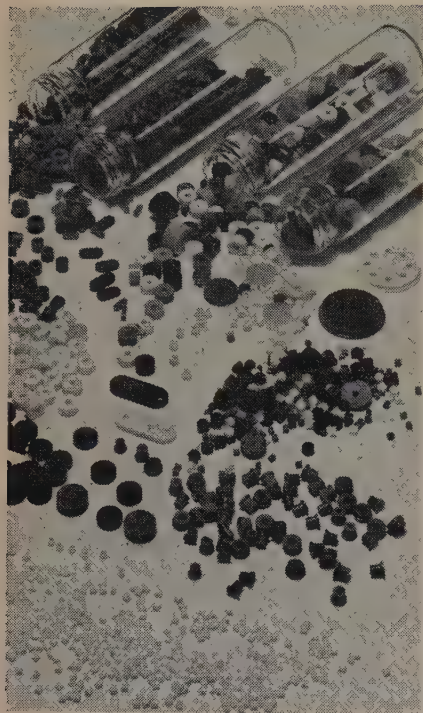
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Shown above are representative glass sealing preforms, produced by Glass Beads Corporation. Beads of required geometry and controlled density are made in a wide variety of sizes, colors and styles for both matching-coefficient and compression-type seals. Specially designed, modern facilities and skilled personnel assure prompt service, highest quality and dependable uniformity. Send drawings for quotation.

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## New Literature

The Lansdale Division of Philco Corp. has made a Transistor Application Guide available in response to industry's many queries concerning the proper selection of transistor types for specific applications. The guide, in booklet form, indicates suitable transistor types for each major application. Transistors are classified in terms of one or two important parameters. Information is primarily presented in graphs and curves for simplicity. Data given by charts is intended to be reasonably typical of performance that has been obtained in practical circuits.

Circle 100 on Reader Service Card

A new group of technical data sheets describing the physical properties of alloys used in the manufacture of semiconductor devices has been released by Alpha Metals, Inc. These latest "Semiconductor Data Sheets" describe the properties of aluminum-silicon, lead-silver and indium-gallium alloys. Part of a continuing series, each data sheet contains a phase diagram of one of these alloys, a description of its phase relationship and crystal structure, properties and fabrication possibilities.

Circle 101 on Reader Service Card

A two-color, four-page brochure has been prepared by Schweber Electronics to aid buyers and engineers in the selection of Vitramon Capacitors. It contains illustrations and details of Axial and Axial-Radial Series and the new ceramic Micro-Miniature capacitors, and lists their availability by part number, capacity, dimensions, etc.

Circle 102 on Reader Service Card

An up-to-the-minute summary of the forms, properties and applications of Dow Corning Silicones is contained in a 16-page brochure. Products reviewed range from adhesives to release agents, laminating resins to rubber compounds, and electrical insulation to water repellents. The table of contents is arranged according to applications enabling quick, easy reference to silicone materials.

Circle 103 on Reader Service Card

For information concerning Transistors, Diodes & Rectifiers, D.A.T.A. offers complete, worldwide, up-to-date Reference Service. Characteristics tabulations in each category reduce the "dogwork" and give immediate information four ways: Listed first in major characteristics sequence, you can quickly locate the type best suited to your requirements, similar types are grouped together. All manufacturers of each type are included in the Type Number Cross-Index. Each manufacturer's complete product line is itemized separately. Complete, superseding editions of each of their three tabulations are issued semiannually, plus a supplement to the Transistor Characteristics Tabulation between each complete edition. Price and information on free offer with each new subscription available from D.A.T.A., Inc.

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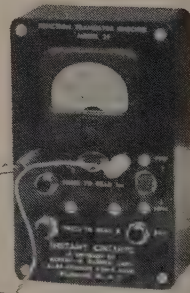
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Circle No. 64 on Reader Service Card

**SEMICONDUCTOR PRODUCTS • MAY 1960**

Wakefield Engineering, Inc., announces the availability of their technical Bulletin No. 260 and Price List on Semiconductor Heat Exchangers, Series 5000, for Medium Pressure Forced Air Cooling Systems using transistors, Zener diodes and rectifiers. Contains a complete description on the material, construction, finish, mounting, and ducting and baffling of the heat sinks. Illustrations, line drawings, and Characteristic Curves are given for each of the five models.

Circle 105 on Reader Service Card

Dialight Digest consists of 24 pages (8½" x 11") of condensed technical data on a wide range of Dialco Pilot Light Assemblies and the lamps for which they were designed. A section is devoted to Lens Holders with lenses for panel mounting, Cable Connectors, and Bracket-Mounted Sockets for small lamps.

Circle 106 on Reader Service Card

The new Kepco catalog (B601) of Voltage Regulated Power Supplies gives full descriptive data of active standard models in the transistorized, vacuum tube, magnetic and hybrid design groups of the company's wide line of power supplies. A new dual index by design group and output voltage range provides easy access to this data.

Circle 107 on Reader Service Card

Performance characteristics, description and tables showing diameters of wire available are shown in CERON ST data sheet, from Kanthal Corp., on resistance alloy wire with new dual layer, high temperature insulation of ceramic and Teflon (TFE fluoro-carbon). Complete specification data is given.

Circle 108 on Reader Service Card

Allied Radio Corporation announces publication of a greatly expanded sixth edition of the Allied Semiconductor Directory. This complete purchasing directory includes the newest power, high-speed switching, high-current, Zener diodes and diffused junction mesa type transistors. Also listed are the latest microdiodes, voltages-variable capacitors and photo-sensitive devices.

Circle 110 on Reader Service Card

Anchor Metal Co. Inc. announces the publication of a booklet written especially for production personnel involved in soft and hard soldering. The 6-page manual "Anchor Solder and Its Proper Application," provides an interesting summary of the origin and uses of the soldering process throughout the world. In addition, there is a section devoted to the soldering of aluminum including tips on the most effective method.

Circle 111 on Reader Service Card

Sprague Electric Company has made available Engineering Data Sheet No. 6201B on their Resin-Dipped Formulation 23 Monolithic Ceramic Capacitors. Sheet lists performance characteristics and gives a Cross Reference Guide.

Circle 112 on Reader Service Card

Abbeon Supply Company has issued Information Bulletin 569 containing facts about Dehumidification for industrial plants, warehouses, stockrooms and laboratories. Answers typical questions in this field and illustrates available equipment with prices for various units.

Circle 113 on Reader Service Card



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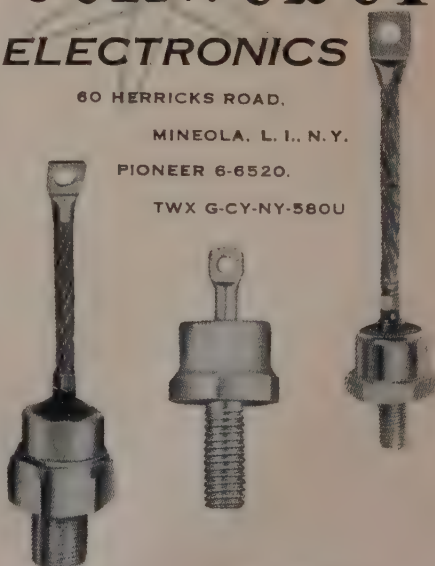
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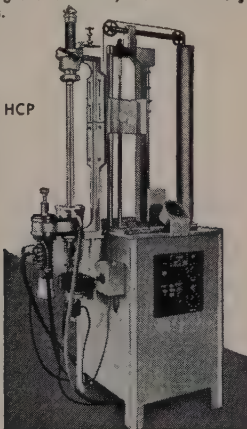


Lepel induction heating equipment represents the most advanced thought in the field of electronics... the most practical and efficient source of heat developed for numerous industrial applications. You are invited to send samples of work with specifications. Our engineers will process and return the completed job with full data and recommendations without cost or obligations.

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## Personnel Notes

William J. Peltz, vice president and general manager of the Lansdale Division of Philco Corporation, has announced new staff and managerial appointments as part of the expansion planning of this division. Stephen L. Levy, assistant to the vice president and general manager of the division; H. Kenneth Ishler, general manager of semiconductor operations; Raymond M. Cotter, director of manufacturing for semiconductor operations; George W. Pratt, director of engineering service; Charles Lupton, director of industrial relations; Cyrus H. Warshaw, director of marketing and William F. Maher, manager of sales.

As part of an expansion and reorganization of General Instrument Corporation's Semiconductor Division, a series of promotions and engineering staff additions have been announced by Maurice Friedman, Vice President and General Manager of the Division. They include: William J. Feldman, Chief Industrial Engineer; Eric J. W. Evans, Chief Germanium Diode Process Engineer; E. Thomas Middleswarth, Chief Glass Technologist; Ralph H. Garten, Senior Industrial Engineer; Lawrence P. Goetz, Senior Process Engineer; Kurt J. Sonneborn, Senior Process Engineer.

The J. T. Baker Chemical Company, Phillipsburg, New Jersey, through its President, Dr. J. R. Stevens, announces the appointment of Dr. Charles H. Schramm as Scientific Director.

Harold C. Potter has been appointed manager of sales for General Electric's Semiconductor Products Department. Mr. Potter's office is located at the Department's marketing headquarters in the Charles Building, Liverpool, N.Y.

Ira W. Hutchison, Manager of the International Department, Dow Corning Corp., Midland, Michigan, has also been named president of its new subsidiary, Dow Corning International S.A.

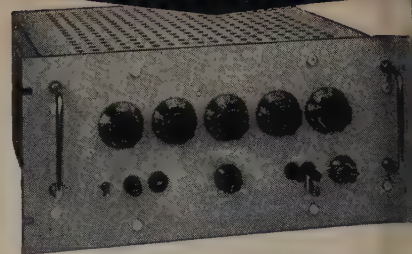
Boonton Electronics Corporation of Morris Plains, New Jersey has announced the appointment of Raymond E. Lafferty as Chief Engineer. Mr. Lafferty will be concerned with the design and development of new test equipment and with application engineering.

Dwight N. Wait has been named general manager of Kemet Company, Division of Union Carbide Corporation it was announced by John D. McQuade, Pres.

Frank G. Gustafson has been appointed supervisor of the process engineering department in Plant 7 at Norton Company, Worcester, Mass. Joining the company in the sales training course in 1952, he has worked, successively, as a grinding engineer, sales engineer, supervisor of the sales engineering department and chief sales engineer of the abrasive division.

Charles H. Sommer was elected president of Monsanto Chemical Company recently and Charles Allen Thomas was elected chairman of the Board of Directors.

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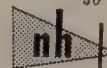
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The appointment of Ernest V. Smith as Field Representative for Schweber Electronics, components distributing firm Mineola, L.I., N.Y., has been announced. A. William Suarez, the company's New England District Manager. Mr. Smith will service components users in the New England area and in and around Schenectady, N.Y. The appointment coincides with the establishment of a regional spot for G. E. Tantalytic (R) Capacitors, Ramon Capacitors and Daystrom Potentiometers, located at 1191 Washington Avenue, West Newton, Massachusetts.

Affiliation of two new executives with Pacific Semiconductors, Inc., and their appointment to key manufacturing positions, was announced recently by Dr. Harry Q. North, president. Robert M. Wood, formerly PSI as Manager of the Transistor Plant. David M. Edwards, has been selected as Manager of Manufacturing Planning and Control. They will report to Harry Lindgren, Manager of Manufacturing.

John Bettencourt has been appointed manager of micro-alloy diffused transistors in an announcement by Edward J. Quirk, semiconductor plant manager for BS Electronics.

Arthur W. Keough has been appointed Quality Control Manager of the Los Angeles division of the Avnet Electronics Corp., it was announced recently by Robert H. Avnet, Chairman of the Board.

Norman J. Golden has been promoted to vice president-research and development of the Semiconductor Division of Hoffman Electronics Corporation. He succeeds Dr. Morton B. Prince, who recently was named vice president and general manager of the division.

Fairchild Semiconductor Corporation has appointed Robert Shultz to head its applications engineering section, Dr. Victor Grinich, Director of Engineering, announced recently. He has been in the solid state electronics field since 1951.

Herbert O. Boellhoff has been named Methods and Procedure Supervisor by Perry Semiconductor. Mr. Boellhoff comes to Sperry with wide experience in the semiconductor and transistor fields.

William W. Taylor has joined the Biddle Company as an account executive to help set up an Electronics Section. He was formerly Ad Manager, General Sales Manager and Staff Assistant to the Marketing Manager for Sangamo Electric Company's Electronic Division.

## BACK ISSUES AVAILABLE

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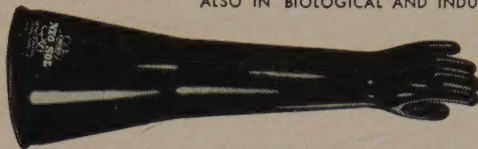
## SEMICONDUCTOR PRODUCTS

Back Issue Dept.

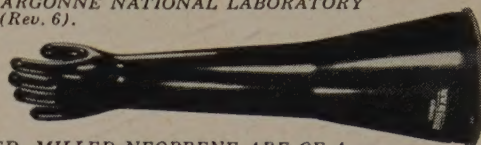
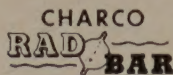
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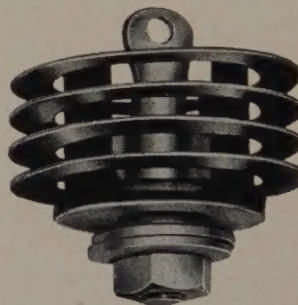


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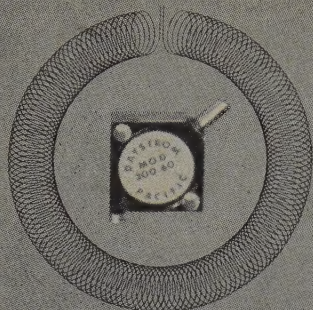
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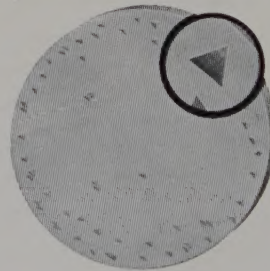
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new transistors from Sprague\*

## SUPER HIGH-SPEED SWITCHING TRANSISTORS TYPE 2N501

	Typical	Maximum	Units
Rise Time ( $t_r$ )	9	18	$\mu\text{sec}$
Storage Time ( $t_s$ )	9	12	$\mu\text{sec}$
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In circuit with current gain of 10 and voltage turnoff.

Also available as special type 2N501A for  
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Write for complete engineering data sheet to the Technical Literature Section, Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.

\* *Sprague micro-alloy, micro-alloy diffused-base, and surface barrier transistors are fully licensed under Philco patents. All Sprague and Philco transistors having the same type numbers are manufactured to the same specifications and are fully interchangeable.*

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